DOCUMENT RESUME

ED 317 433 SE 051 352

AUTHOR Lightle, Juliana
TITLE The Future Labor Force and Workplace and the Scientific and Engineering Workforce: Implications for Society and Business and Potential Solutions.
INSTITUTION Human Resource and Career Solutions, Worthington, OH.
PUB DATE 89
NOTE 72p.
PUB TYPE Information Analyses (070) -- Viewpoints (120)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS College Mathematics; College Science; Continuing Education; Engineers; *Futures (of Society); Higher Education; *Labor Force; Labor Market; *Labor Needs; Labor Supply; Mathematics Education; *Minority Groups; Science and Society; Science Education; *Scientific Personnel; Scientists; *Supply and Demand

ABSTRACT

This report examines the future shortages of scientists and engineers and suggests potential solutions to the shortage. The first section presents general demographic data and trends and interprets what this information suggests for the future economy and business in general. The second section considers the supply of physical scientists and engineers, both currently and in the future; there will be a shortage for both at the Ph.D. level. The third section provides potential solutions to social and labor force needs and problems. Solutions presented include: (1) Increase and expand intervention programs to encourage minority and female participation in scientific disciplines; (2) Reform elementary and high school math and science education; (3) Abolish discrimination in the work place; (4) Increase scholarships and funding; (5) Provide long-term continuing education programs for scientists and engineers; (6) Develop policies and laws to facilitate the retention of educated foreign nationals; and (7) Mandate programs/training to foster the value of diversity. (YP)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED317433

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

Minor changes have been made to improve reproduction quality.

Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Juliana Lightle

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

THE FUTURE LABOR FORCE AND WORKPLACE

and

THE SCIENTIFIC AND ENGINEERING WORKFORCE:

Implications for Society and Business
and
Potential Solutions

Juliana Lightle, Ph.D.
Human Resource and Career Solutions
300 Medick Way
Worthington, OH 43085

SE051 352

BEST COPY AVAILABLE

Preface

This study is presented in several sections. The initial portion covers general demographic data and trends and what this information suggests for the United States economy and business in general. The second section looks more specifically at the supply of scientists and engineers, both cur
future. The third portion provides potential solutions to both social and labor force needs and problems.

A number of sources were used for data. These include publications (see References) and discussions with many people, including researchers at Battelle's Human Affairs Research Center (HARC), scientific and engineering recruiters, academicians, and various individuals whose life work is tracking and analyzing population trends and their implications.

This study was originally undertaken while the author was a manager at Battelle in Columbus, Ohio. Many thanks go to a wide variety of individuals there who provided comments, critique, and editorial and typing assistance.

EXECUTIVE SUMMARY

The General Population

The population of the United States is changing and will continue to change dramatically. Current data and future projections include the following:

- 30,000 people are over 100 years of age. That number is expected to increase to 100,000 by the year 2000.
- 2.2 million are over 85 and almost 50 percent of them vote in presidential elections.
- By 2080, people 65 plus will be one quarter of the population.
- 20 million households have only one occupant.
- 59 percent of first graders will have lived with a single parent by age 18.
- 25 percent of children born are born to unmarried women.
- Only 11 percent of households fit the traditional family structure.
- By 2020, current minorities will make up 50 percent of the population.
- By 2000, Texas to California will be bilingual.
- By 2000, only 15 percent of new workers will be white males.
- By 2000, 67 percent of new workers will be female, and 47 percent of the total work force will be female.
- By 2000, individuals 35-47 will increase by 67 percent compared to a total population increase of 15 percent.
- Youth will decline to only 13 percent of the population. The Northeast and Midwest will show the largest declines in youth.
- The average age of workers will continue to increase. By 2000, it will be 36. Until 1970, the average age had been decreasing throughout United States history.
- 45 percent of baby boom men can expect to divorce.
- The new "rich" are dual career couples. The new poor are single mothers.
- Immigrants (legal) will comprise one-quarter of the population growth by 2000. These immigrants will be from Asia, South America, and Africa, not from Europe.
- Women are becoming more career oriented and males less so. Both are becoming less family oriented.

The Work Place and Labor Force

The nature and types of work are changing as much as the labor force but not necessarily in compatible directions. Projections include the following:

- The fastest growing jobs, technicians, health care professionals, engineers, scientists, and lawyers, all require education beyond high school.

- By year 2000, 1/3 of positions will require a college degree. Currently, only 22 percent do so.

- At the same time, for every high technology position, there are six nontechnological jobs.

We have not created well paying jobs in the service sector as we previously did in manufacturing. We are moving away from an economy with a large middle class into one in which we have a small number of executives and professionals at the top and a large number of low level service, clerical, and part-time people at the bottom, many of whom are women heading families or minorities. Simultaneously, many of these positions are becoming automated. This may increase unemployment, especially for blacks and Hispanic males who currently hold the largest portion of such positions.

As automation increases, the basic skill level requirements increase. Recent studies indicate that young Americans lack even these basic skills. For example, in a recent study:

- Only 44 percent of whites, 20 percent of Hispanics, and 8 percent of blacks could make change for a two-item restaurant meal.

In recent surveys companies are reporting shortages of qualified applicants for even low level positions. People cannot read and compute basic arithmetic.

Impact of Population and Work Force Changes

Major impacts of the changes just cited include:

- National economic growth will decrease.

- Demand for population sensitive goods will decrease while demand for income sensitive goods will increase.

- Labor markets will tighten.

- By the time baby boomers start to retire around 2010, there will be approximately one worker per retiree.

- It will become increasingly difficult for companies to hire youth for cheap wages.

- The aging work force will increase the rigidity of the economy.
- Due to older workers and dual career workers, the work force will become more inflexible unless company policies change.
- Early retirement will cost more.
- Because older workers cost more, companies may become less competitive.
- Because of increased number of women at work, day care and preschool will be regulated and subsidized.
- Benefit structures will change to meet increased diversity.
- Public benefit programs may be geared solely to those with lower incomes. This could include social security.
- More middle aged workers will be caring for both their children and parents simultaneously. Currently, 25 percent of workers over 40 care for their parents.
- Immigration will become increasingly important to economic growth.
- The work force will be increasingly culturally diverse.

The Science and Engineering Labor Force

One of the problems with demographics and future projections about the scientific and engineering labor force is disagreement on just how many scientists and engineers there are. For example, the Bureau of Labor Standards (BLS) says there are 1,331,747 engineers, whereas the National Science Foundation (NFS) count is 2,634,900, a figure nearly double the first one. The difference, in part, is due to the fact that NFS counts all with an engineering background regardless of present status as engineers. BLS uses a narrower definition. Without accurate data it is difficult to predict shortages or surpluses or to create and implement national policy. On the other hand, whether an engineer is counted as an engineer, a manager, or a scientist is not important if the primary concern is technological literacy.

The potential shortage problem is compounded by confusion over definitions of shortage. Put simply, all data indicates there will be a shortage if by shortage one means a company being able to obtain the best graduates from the best schools at a price they prefer to pay. Generally, at the non Ph.D. level there are no present shortages of engineers except for chemical engineers and less so for civil. These spot shortages are representative of the historically rather typical spot shortages that have occurred periodically for years.

However, the future will look very different unless interventions occur.

Data indicate that:

- The number of white males that traditionally pursue science and engineering is decreasing.
- Fewer students indicate an interest in science and engineering.
- The increase in minorities and women studying science and engineering has ceased.
- The influx of foreign nationals who remain may cease as their countries of origin become more prosperous and there are good jobs for them at home, e.g., Korea.
- Since physics and math students are decreasing, there will be fewer in these disciplines to fill the gap in spot shortage situations.
- The percentage of native U.S. students in physical sciences and engineering continues to decrease, e.g., 55% of engineering Ph.D.'s go to foreign nationals.
- Engineering and science faculty are increasingly foreign born, e.g., 39% in electrical engineering.

At the Ph.D. level, there will be a shortage across the board. This will be exacerbated by large numbers of retirements at academic institutions which will surge in the mid-1990's.

Potential Solutions to Shortages in Science and Engineering

These shortage issues directly relate to the following broader societal issues:

- The extent which society considers it desirable for minorities and women to hold higher positions in the work place.
- The basic skills educational crisis.
- The manner in which society integrates the new immigrants.
- Meeting the needs of changing family and lifestyle structures.
- Decreasing youth and increasing numbers of older individuals.

The minority population is increasing while the white population is decreasing. Except Asians, these groups are grossly under represented in science and engineering and also experience broad based educational difficulties which they must overcome to increase participation in technological fields. This will take massive interventions. Experts agree that such interventions must occur no later than sixth grade to be effective. That means we must start immediately if we want to impact who will complete

engineering degrees in the year 2000. For minorities factors which must be overcome include:

- Poverty and cultural prejudice against academic achievement for blacks.
- Poor academic preparation.
- Few role models e.g., black scientists and engineers number only 2.6 percent of the black population. In 1988 only 59 blacks, Hispanics, and native Americans earned a Ph.D in engineering as compared to 1,441 foreign nationals and 3,686 total.
- Reduced college attendance rates.
- Lower educational level of parents.
- Less family financial support for college.
- Higher unemployment rates for minority scientists and engineers and lower salaries as compared to white males.

The lack of women pursuing science and engineering is caused by many of the same factors that affect minorities.

- Higher rates of unemployment for female scientists and engineers.
- Lower salaries, e.g., expert estimates calculate $250,000 less salary for a female Ph.D. over a 30 year career span.
- Fewer role models, e.g., only 17.5% of female faculty are tenured whereas 73.9% of male faculty are.
- Less family financial support for college.
- Receipt of fewer research assistantships for graduate school.

Other factors which negatively impact female participation in scientific fields include:

- Family and social pressures against science and engineering as appropriate careers for females, e.g., studies show girls who prefer science are viewed as less popular and less attractive.
- Prejudice of both foreign born and U.S. male faculty against women students; this is most prevalent in the physical sciences and engineering.
- Fewer opportunities for advancement.

Another factor that may affect minority and female career preferences deals with the social stereotypes of engineers and scientists, i.e., science and engineering are seen as lacking political power and prestige; scientists are

viewed as weird. Other professions are viewed as yielding greater returns for the investment.

The U.S. educational system is failing to provide adequate quantitative education not only for females and minorities, but for the entire student population. Our students fare dismally in international testing. Few U. S. high schools require four years of science or math. Less than half of high school science curricula have laboratory work. Federally funded fellowships have fallen from 60,000 in 1970 to less than 13,000 in 1986. Out of 10,000 high school sophomores, only 20 will earn a Ph.D. in science or engineering.

There are solutions to these problems, but they will require massive, concerted national effort from all sectors, education, business, and society as a whole. Potential solutions include:

- Immediately increase and expand intervention programs to encourage minority and female participation in scientific disciplines. Train engineering and science faculty regarding appropriate behavior to encourage rather than discourage female and minority participation.

- Reform elementary and high school math and science education, i.e.,require more training for teachers, require more science and mathematics, and alter the way in which mathematics and science are taught.

- Abolish discrimination in the work place by equalizing salaries and promotional opportunities.

- Increase scholarships and other funding for technological/quantitative disciplines.

- Provide long-term continuing education programs for scientists and engineers. In conjunction with the continuing education, encourage retention of older employees via restructuring of benefits and social security.

- Develop policies and laws to facilitate the retention of quantitatively educated foreign nationals.

- In the work place, mandate programs/training to foster the value of diversity.

Conclusion

The future work force and work place will look different from today's. There will be more minorities and women and fewer white males. Skill requirements will increase. Shortages of scientists and engineers are likely to occur.

The future of the U.S. depends upon how well we handle these changes. We cannot change who has been born, but we can alter the effects by changing attitudes. We can focus on outcomes, on what we want our society to become for all of us. When we analyze basic and scientific education and the labor

force, we must also look at the overall system of which they are a part. We must review our values and motivations.

Many people are studying the data and addressing the problems discussed in this paper. If we keep hammering away at them, we can mold them into a positive future.

GENERAL POPULATION
AND LABOR FORCE CHANGES

The General Population

The United States population is rapidly changing. Among experts, there is absolutely no disagreement about these changes in the general population or the labor force either currently or for the next 15-20 years. Everyone who will be working in the year 2000 is already born, so these are not crystal ball projections. They are facts.

To get us thinking about some of these facts, let's consider a few simple questions:

1. Currently, how many people in the United States are over 85?

2. How many households are there in which the male makes less money than the female?

3. What percentage of children born in the early 1980's will live with only one parent before age 18?

4. How many children are born out of wedlock?

5. What is the fastest growing group in the United States population?

6. What percentage of new workers in the year 2000 will be white males?

7. What percentage of new jobs are created by small businesses?

To a certain extent, the answer to these questions and many others like them, their implications, and how this society deals with them, will form the destiny of the United States. The answers to the above questions are all found in the 1980 U.S. Census and subsequent Labor Department updates. They are not guesstimates; they are reality.

There are 30,000 people in the United States over 100 years of age. Projections indicate that this number will increase to 100,000 by the year 2000, assuming the current death rate continues. 2.2 million people are over

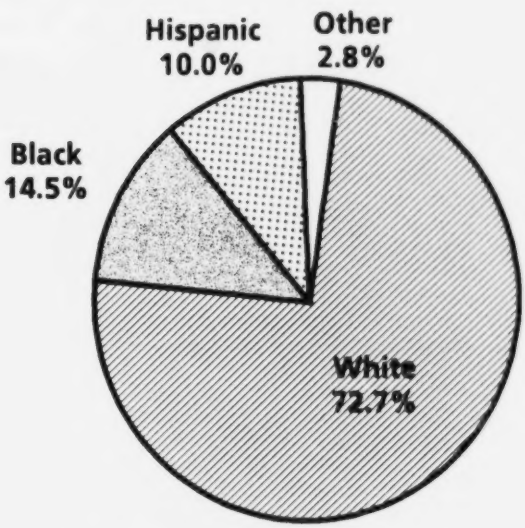
85 and nearly fifty percent of them vote in presidential elections. By 2080, people 65 and older will make up one quarter of the population.

In the 1980 census, there were six million households in which the female partner made more money than the male partner. Twenty million households had only one person. Historically, men tend to seek part-time work around the age of 55. Women's long term work behavior is unknown as yet. Of children born in 1983, fifty nine percent will live with a single parent by the age of 18. Twenty five percent of the children born are born to unmarried women. Teenage pregnancies number more than 50,000 per year. Twenty-five percent of first graders live in poverty. Only eleven percent of households have the traditional family structure, a working father, housewife mother, and two or more children. All of these facts indicate dramatic changes for our society and consequently, for the future labor force.

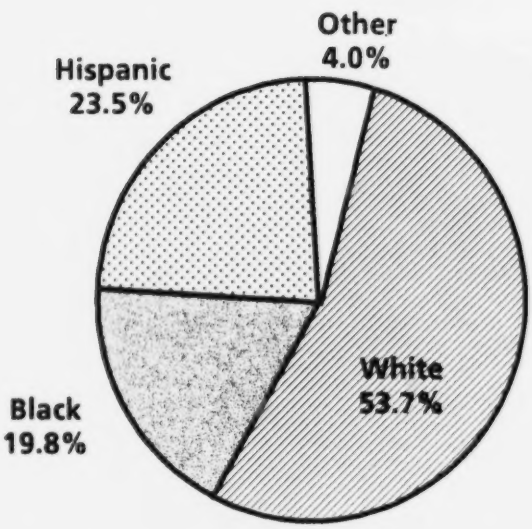
The Hispanic population is growing faster than that of any other group. (It is somewhat misleading to talk about Hispanics as a whole because data on Cubans, Puerto Ricans, and Mexicans vary greatly; but for the purposes of this analysis, they are grouped.) The average Hispanic birthrate (per female) is 2.7, black is 2.4, and Caucasian is 1.7. (To keep even, the birthrate must be 2.1. After WWII, the Caucasian birthrate was 2.9.) The average ages also differ and correspond to birthrate data, i.e., mean age of Caucasian females is 31, black females is 25, and Hispanic is 22. It is obvious who has the potential to have the most children. By 2000, there will be 44 million blacks and 47 million Hispanics in the United States. By that time, in California, the current Caucasian majority will be in the minority. In 1986, in Texas, forty six percent of the school population was minority, i.e., non-Anglo.

Obviously, in the future, the population and workforce will have a very different complexion than at present. In 1987, twenty nine to thirty percent of 5-17 year olds were minorities. The Census Bureau estimates that by 2020, minorities 5-17 will increase to forty eight percent (see Figure 1). By 2000, only fifteen percent of new workers will be white males. Two-thirds of new workers will be female, Hispanics will account for twenty nine percent, blacks eighteen percent, and Asians and other racial groups will account for eleven percent. Obviously, the new worker is even more likely than ever to be black,

Racial-Ethnic Make-up
5-17 Year-Olds



Current –1982



Projected – 2020

Figure 1

Lightle1vg-1

Hispanic, or Asian (see Figure 2). This will not change the overall workforce immediately, due to the domination of baby boom workers, who will cause the average age of workers to increase for several decades into the twenty-first century.

The aging of the workforce (see Figure 3) is due to fewer overall births. The United States population is growing more slowly than at any time except for the Great Depression decade. Thus, we see a slowing of both population and workforce growth. Although it is impossible to predict immigrant growth due to external factors, e.g., revolutions, immigrants are expected to represent the largest share of population increase since World War I. Furthermore, these immigrants will not be from European countries as in the past, but from Latin America and Asia. If the legal immigration rate continues as at present, immigrants will comprise as least one-quarter of the population growth. However, if one counts illegal immigrants also, nearly one half of growth will be immigrants.

Other factors also alter the workforce of the future. People stay single longer. For example, 2.3 million men age 25-34 lived alone in 1985, but only 0.3 million did so in 1965. Marriages are of shorter duration and there is more divorce, e.g., forty five percent of baby boom men can expect to divorce. Over two-thirds of wives aged 25-34 were in the labor force in 1986. Projections indicate that men of all ages will spend less of their lives working and women will spend more. Women's attitudes toward work and family are becoming more like those of men (Figure 4), that is, they are becoming more career oriented. Two other female related factors affect the workforce and society as a whole. When there is a dual career couple, households earnings rise substantially. On the other hand, single women working to maintain a family are the new poor.

When trends are studied, generally the emphasis and interest are centered on large corporations. However, large corporations do not control future job growth. Forty percent of new jobs are created by small businesses. That proportion is expected to grow (Guess Who's Coming to Work, pp. 10-11).

Most New Entrants to the Labor Force Will Be Non-White, Female, or Immigrants

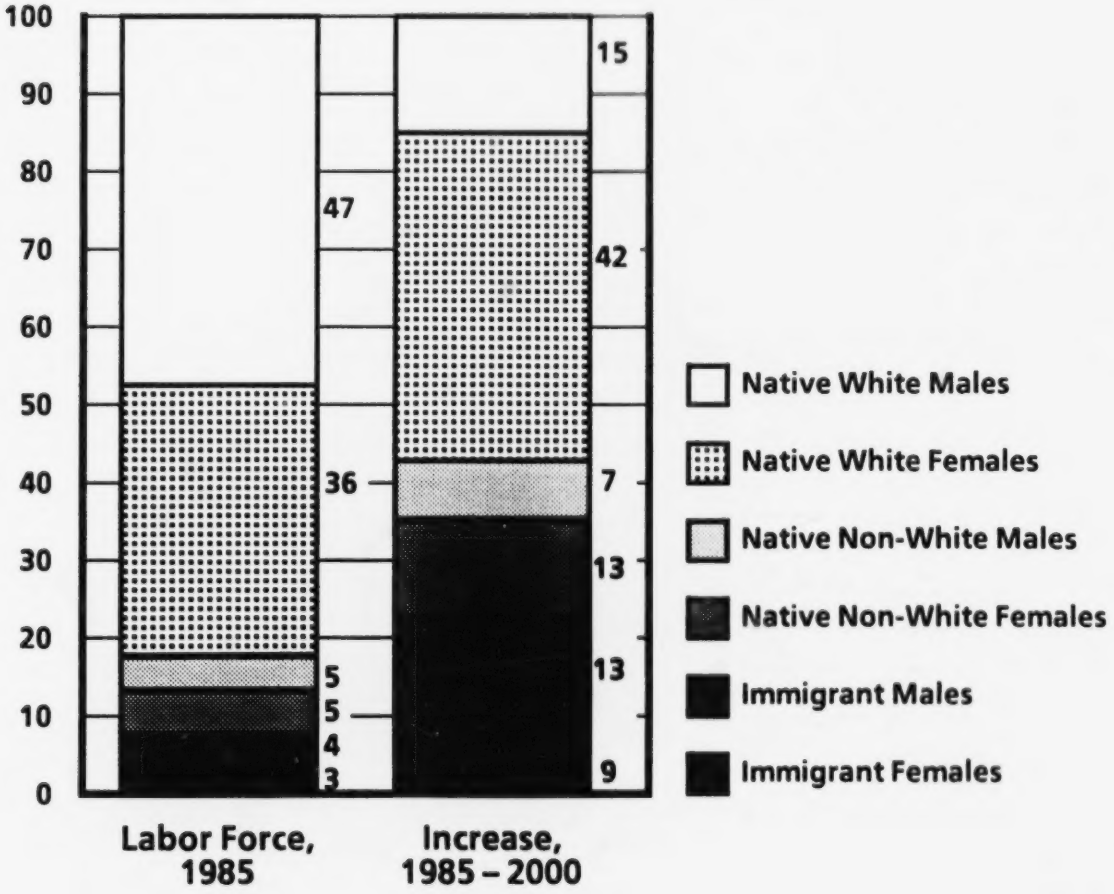


Figure Two

Source: Hudson Institute

The Middle Aging of the Workforce

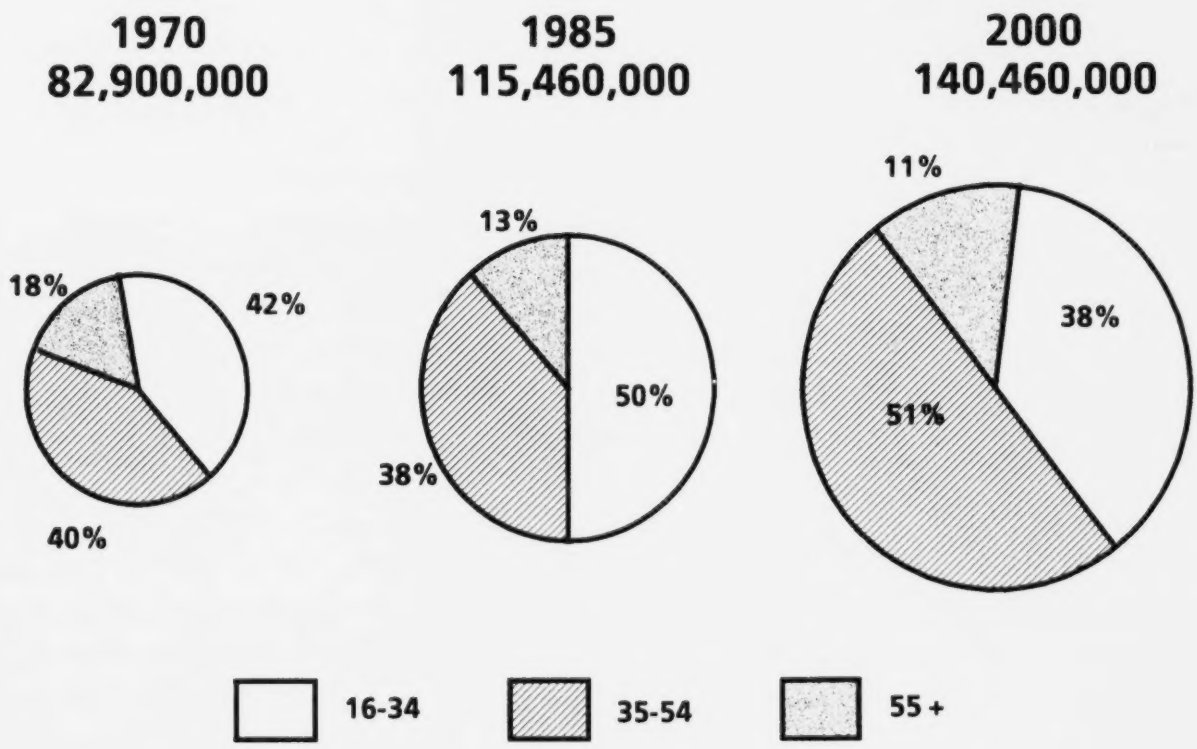


Figure 3

Lightle1vg-3

Which Is More Important, Family or Career? Male and Female College Students:

(1952-1980)

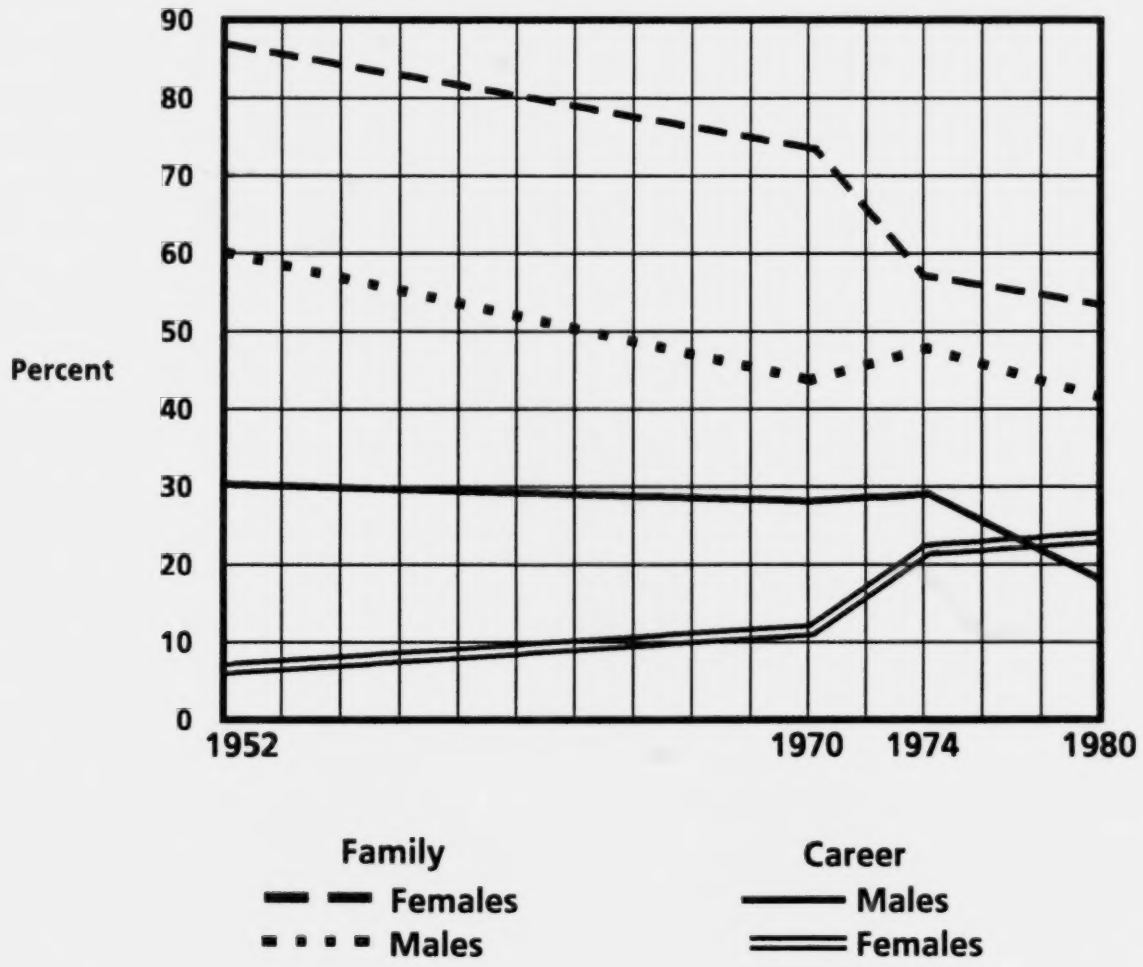


Figure 4

Lightle1vg-4

The Jobs of the Future

Not only is the labor force changing, but also the nature and types of work. Many unskilled jobs will disappear, whereas, skilled and professional work will increase. Therefore, the skill mix is rapidly moving up the scale. Future jobs will demand a higher level of language, math, and problem-solving skills. Although we are discussing work as a whole, it is important to remember that different industries require different skill mixes. Nevertheless, looking at the accumulated effects of reviewing industry types, the projected growth areas are for professional, technical, managerial, sales and service positions, not factory jobs. Table 1 shows the changing growth rates for various job types of occupations. The fastest growing jobs, technicians, health care professionals, engineers, scientists and lawyers, all require education well beyond high school. It is projected that by year 2000, one-third of positions will require a college degree as opposed to 22 percent now. The only fast growing job type which does not have higher level skill requirements is service occupations.

The types of services will grow in number and vary widely. Although many of the fastest growing positions, including several just mentioned, have high technological requirements, many of these service occupations do not. Almost all the literature on this topic tends to disregard the fact that for every high technology position, there are six non-technological jobs. These are jobs such as nurses' aids, waiters and waitresses, retail sales personnel, cashiers, clerks, food workers, clerical personnel, and drivers. The question then becomes, what kind of educational requirements are there for these positions? We also need to look, of course, at the reasons frequently given for educating people in the first place. This will be touched upon again later. The facts indicate that United States society has not created a lot of well paying service positions comparable to those which once occurred in the manufacturing sector. We are in danger of having overly educated people (if job fit is the primary reason for education) for many of the new positions, and not enough skilled professionals and technicians on the other hand, for other highly skilled positions, e.g., engineers. To quote Harold Hodgekinson of the Institute for Educational Leadership:

Table One

The Changing Occupational Structure, (1984-2000)

Occupation	Current Jobs (000s)	New Jobs (000s)	Rate of Growth (percentage)
Total	105,008	25,952	25
Service Occupations	16,059	5,957	37
Managerial and Management-Related	10,893	4,280	39
Marketing and Sales	10,656	4,150	39
Administrative Support	18,483	3,620	20
Technicians	3,146	1,389	44
Health Diagnosing and Treating Occupations	2,478	1,384	53
Teachers, Librarians, and Counselors	4,437	1,381	31
Mechanics, Installers, and Repairers	4,264	966	23
Transportation and Heavy Equipment Operators	4,604	752	16
Engineers, Architects, and Surveyors	1,447	600	41
Construction Trades	3,127	595	19
Natural, Computer, and Mathematical Scientists	647	442	68
Writers, Artists, Entertainers, and Athletes	1,092	425	39
Other Professionals and Paraprofessionals	825	355	43
Lawyers and Judges	457	326	71
Social, Recreational, and Religious Workers	759	235	31
Helpers and Laborers	4,168	205	5
Social Scientists	173	70	40
Precision Production Workers	2,790	61	2
Plant and System Workers	275	36	13
Blue Collar Supervisors	1,442	-6	0
Miners	175	-28	-16
Hand Workers, Assemblers, and Fabricators	2,604	-179	-7
Machine Setters, Operators, and Tenders	5,527	-448	-8
Agriculture, Forestry, and Fisheries	4,480	-538	-12

Source: Hudson Institute

"The economy is moving from a work force that had a majority of people in the middle who were well paid and moving ahead to a work force in which we have a small number of high-paid executive and professional people at one end and a large group of low-level service, clerical, part-time and female workers at the other--and nothing much in the middle. It hasn't happened yet. We are about a tenth of the way, but in 20 years it's going to happen unless we do something about it." (Guess Who's Coming to Work, p. 10)

To compound the situation, productivity gains in service industries have been traditionally weak. On the other hand, these same service industries have provided many jobs for low skilled workers. In the future, fewer entry level workers, changing attitudes toward work, and automation of many of the service industries will lower the number of unskilled jobs and potentially raise unemployment. Therefore, certain types of basic technology education will become increasingly important.

The impact of these changes for the minority population is enormous. If current and historical employment and education trends continue, the majority of blacks and Hispanics will continue to occupy the ranks of the lower skilled and unemployed. If black men merely hold on to the same share as their current share of occupations, they will hold a declining fraction of all jobs (see Table 2).

Even if many of the new jobs require only rudimentary skills, it is questionable whether new workers with these basic skills can be found. A recent study by the U.S. Department of Education found that among 21-25 year olds:

"- only three-fifths of whites, two-fifths of Hispanics, and one-quarter of blacks could locate information in a news article or almanac;

- only one-fourth of whites, seven percent of Hispanics, and three percent of blacks could decipher a bus schedule;

Table Two

Black Men and Hispanics Face the Greatest Difficulties in the Emerging Job Market

Group	Share of Current Jobs	Implied Share of New Jobs (1985-2000)	Share of Labor Force Growth
Women	45.0%	50.5%	59.3%
Blacks	9.9%	9.5%	19.7%
Black Men	4.9%	3.8%	7.7%
Black Women	5.1%	5.6%	12.0%
Hispanics	6.4%	5.0%	22.0%
Ages 16-24	19.1%	17.9%	-9.6%
25-44	51.6%	53.0%	44.8%
45 +	29.3%	29.1%	64.8%

Source: Hudson Institute Projections

- only 44 percent of whites, 20 percent of Hispanics and eight percent of blacks could correctly determine the change they were due from the purchase of a two-item restaurant meal." (Workforce 2000, pp. 102-103)

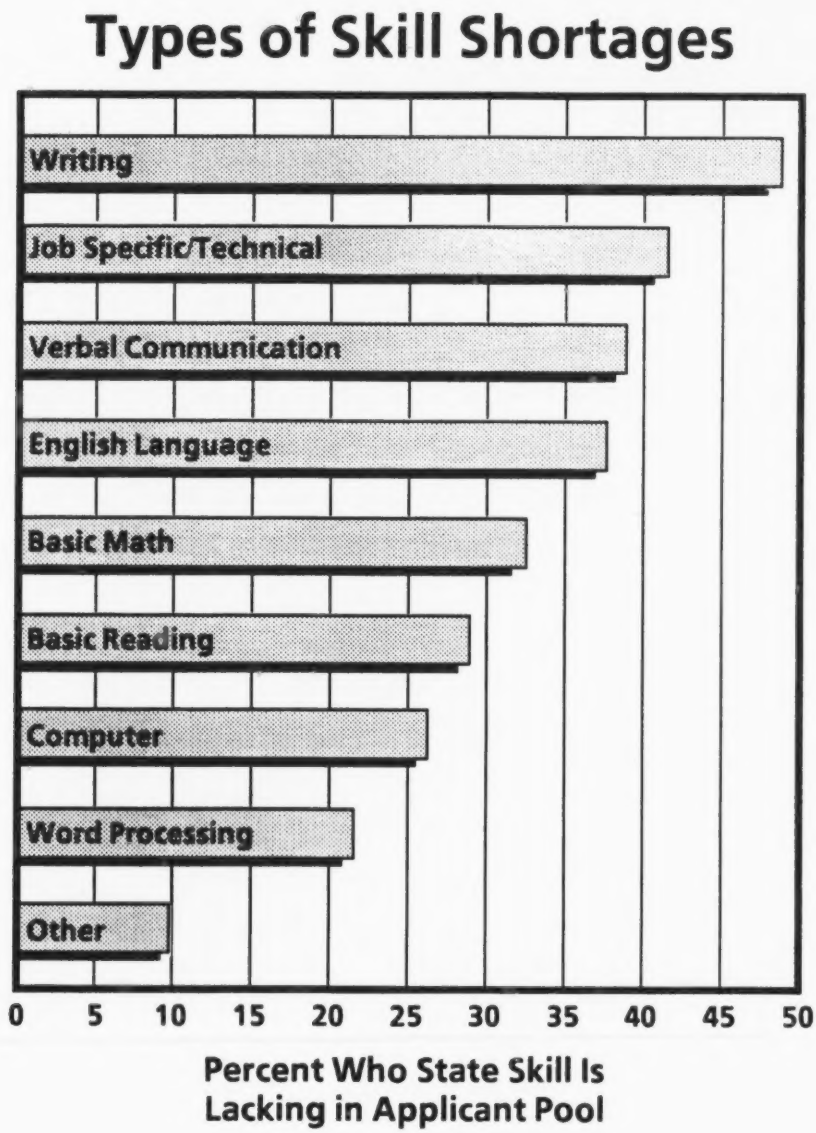
Even the most unskilled service positions tend to require basic language and math skills.

Presently, many companies report a shortage of needed labor. In a recent issue of "Personnel Administrator," an article reporting on an American Society of Personnel Administrators (ASPA) survey indicates that recruitment in many occupations has become a seller's market. Generally, employers reported shortages in all types of occupations, with the degree of shortage varying among regions. However, the real emphasis was on skill shortages. Table 3 indicates these shortages. It appears that the U.S. educational system is failing to prepare individuals even for basic unskilled work. This will be discussed more fully in a later section.

Even the most liberal estimates of population growth indicated a growth slowdown. Using the Hudson Institute's population growth estimates, by 2000, within the United States, there will be either 256 or 281 million people depending on whether one uses the most conservative or more liberal estimate. Any sizeable changes in fertility, death, and immigration rates could affect these figures substantially. As previously mentioned, the greatest uncertainty centers on immigration numbers.

Corresponding to the population growth slowdown, labor force growth will continue to diminish, but the rate of labor force participation will remain somewhat higher than might otherwise be expected because a greater percentage of the population works than has been true historically, women being the prime example. Furthermore, changes in birth and death rates have minimal effect on the labor force short term. The actual size of the slowdown depends upon the economy and which economic scenarios one chooses. With slower labor force growth comes slower national economic growth. Furthermore, as the economy increasingly changes from manufacturing to service centered, it becomes more difficult to readily measure productivity and growth.

Table Three



Source: ASPA Survey

Impacts of Population and Labor Force Changes

What does all this data mean for the United States as a whole and more specifically, for business? Workforce 2000 cites several ways in which slower population and workforce growth will impact the economy:

- The national rate of economic growth will fall well below what it would be if the nation's population and work-force were increasing at the rates of the 1960's and 1970's because it will decrease demand for such products as food, cars, and housing. Productivity increases will, therefore, account for a greater percentage of economic growth.

- Demand for income-sensitive goods, e.g., restaurant meals, luxury goods, (as opposed to population-sensitive) will drive economic growth. Therefore, growth in these income-sensitive sectors will be greater.

- Labor markets will be tighter, due to the slower growth of the workforce and a smaller reservoir of well-qualified workers. (p. 79)

Another area greatly affected by demographic trends is the aging of the population and workforce. The huge baby boom cohort (born between 1946-1961) will gradually increase the mean age of the population so that by 2000, this average will be 36, higher than at any time in U.S. history. Until 1970, the average population age had been declining.

The effects of this are numerous:

- The middle aging of society will occur. By 2000, the number of individuals between 35-47 will increase a huge 67 percent. Compare these figures with a total population increase of only 15 percent and the change becomes very obvious.

- The number of youth will decline substantially to 13 percent of the population. The degree of decline will vary substantially by region with the largest decreases in the Northeast (43%) and Midwest (35%), and a slight increase (2%) in the Southwest.

- This older, more stable workforce will improve productivity, and the proportion of the population not in the labor force will drop. However, this will turn around sharply around 2010 when the first of the baby boomers begin to retire, possibly causing severe problems in the decades following.

- Because there will be more people in middle age and because historically such people have higher savings rates, the national savings rate will probably rise.

- It will become increasingly difficult for companies to hire young people at cheap wages. The beginnings of this are already evident in the food service industry. (Also, young people are becoming less willing to work for cheap wages.)

- Since older workers are generally less flexible, e.g., more reluctant to move, the aging workforce may increase the rigidity of the economy. (They could also take the cheap wage jobs mentioned above.)

- The shortage of young workers could decrease a company's ability to change rapidly. It will become more difficult for a company to use new hires to begin a new endeavor while simultaneously laying off older workers. Early retirement will cost more and wages of youth may be higher. These problems will be greatest in areas such as the Northeast and Midwest where out migration of youth has been and continues to be most severe.

- Older, more experienced workers cost more and, therefore, may make a company less competitive, especially in industries which are production centered, e.g., automobile.

- There may be a squeeze on middle aged workers, a collision between a company's desire to decrease middle management and simultaneously reduce vulnerability to demographic non-competitiveness. Often older workers' primary value is only to their present employer. Therefore, in a lay off, they have a difficult time finding a corresponding new position. If the economy is in a rapid change state, the likelihood of such lay-offs increases. The former stability of increased earnings until retirement may not continue.

- Industries that depend on a young workforce, e.g., higher education, rental construction, for market growth will be particularly affected. (Workforce 2000, p. 81)

Another major area of change is the increasing number of women in the workforce. If recent trends continue, by the year 2000, 47 percent of the workforce will be women. This increase is primarily due to more women with school age children working. "Three-fifths of new entrants to the workforce will be women (Workforce 2000, p. 85)." Nevertheless, women will continue to be concentrated in female dominated, lower paying occupations. Given the large number of women currently in professional schools, a substantial increase of women in the professions is also projected. In spite of all the data on increasing workforce participation by women, there are signs that it may not continue. Due to inflexible working arrangements and day care problems, mothers of younger children are indicating a desire to work less (Workforce 2000, p. 89). Discrimination may play a role here also. A recent book by Battelle's Human Affairs Research Center indicates that "two-thirds of the wage differences between white women and white men and three-quarters of the difference between black women and white men could not be explained by human capital factors (The Changing Lives of American Women, p. 114)." Workforce participation may drop and could further reduce the number of younger workers unless employers develop new policies to better provide for dual earner and

single parents and pay more equitably. As the rapid increase of women working levels off, the economic growth due to this increase will also taper off.

Impacts of workforce feminization are numerous:

- Day care and preschool education will become more regulated and subsidized and government and industry will become more involved. (Note: This change is due also to increasing data on the positive aspects of good day care for the education of disadvantaged children, e.g., Head Start.)

- The tax system will change periodically as society struggles with the issues of fairness and the desire to promote families.

- Due to dual career families, the workforce will become increasingly inflexible unless companies increase efforts to help with job changes and related dual career issues. This will reinforce the previously mentioned age inflexibility.

- Sex discrimination and wage differentials may be gradually alleviated.

- Flexible jobs, e.g., part-time, stay-at-home, will increase.

- Benefit structures will increase in flexibility to meet the needs of an increasingly diverse workforce.

- Public benefit programs are more likely to become geared toward the needs of lower income families and individuals.

A few companies are already becoming aware of and are trying to deal with these issues. Dupont, for example, has conducted an employee survey to zero in on family issues. They found that 25 percent of employees had children who needed day care, 70 percent wanted time off to care for ill children, 90 percent of those who were childless planned to have children within three years, and 40 percent of management-level women avoided high level jobs for family reasons.

Caring for children is one side of an increasingly sharp two-edged sword. In 1988, twenty-five percent of workers over forty were caring for elderly parents. As the population ages, this will increase. Therefore, many middle aged workers will be caring for both older children and parents simultaneously. This sandwiching greatly increases family responsibilities (women do the majority of the caring for elderly parents) and the stress load. Doubtless these factors relate to the skyrocketing workers compensation stress claims.

Dupont also discovered that new appropriate policies were useless without line management cooperation and that line managers often were the last to adapt to these necessary changes. Companies will have to provide management incentives and training to help managers effectively cope with the future workforce.

Whether minorities holding an increasingly sizeable portion of the workforce is a positive or negative for minorities themselves, particularly blacks and Hispanics, is uncertain. "In fact, by the year 2000, black women will outnumber black men in the labor force (Workforce 2000, p. 89)." There is no data on how this will impact the black community.

Table 4

BLACKS AND HISPANICS ARE MUCH LESS SUCCESSFUL IN THE LABOR MARKET

(1983)

	White	Black	Hispanic
Labor Force Participation	64.3%	61.5%	63.8%
Unemployment Rate	8.4%	19.5%	13.7%
Median Family Employment (Weekly)	$487	$348	$366
Percent Below Poverty	12.1	35.7	28.4
Median Years of Schooling	12.8	12.5	12.1

Source: U.S. Bureau of Labor Statistics, U.S. Bureau of the Census.

(Source: Workforce 2000)

By almost every measure of employment, labor force participation, earnings, and education, blacks and Hispanics suffer much greater disadvantages than whites (see Table 4). To these statistical indices one must add the extensively analyzed and debated indications of social disadvantage, such as poor performance in schools, greater dependence on welfare, greater incidence of broken families and children born to unmarried mothers, and higher rates of criminal arrest.

In addition, as previously noted, blacks and Hispanics are overrepresented among declining occupations and are concentrated in a few central cities with problems. To compound these problems, many of the new service occupations and industries are located outside these central cities. If employers, instead of hiring or training minorities, choose to bid up the wages of the smaller number of white labor force entrants and or substitute capitol for labor and move job sites, blacks will be an at risk group (many consider that to be the case now).

Burgeoning immigration will also affect the labor force. Contrary to popular belief, historically immigration has benefitted the U.S. economy. In areas with large influxes of immigrants, e.g., Los Angeles, job growth has been well above the national average. Furthermore, the evidence suggests that immigration does not negatively affect native minority job prospects. One of the fastest growing areas of the country, the Southwest has also experienced one of the highest immigration levels. Asian immigration has been particularly important in maintaining the scientific and technological workforce, which will be discussed in greater detail in the following section.

THE SCIENCE* AND ENGINEERING LABOR FORCE

* This data and discussion concentrate on natural and physical scientists and engineers, not the social scientific disciplines.

Before we dig deeper into the demographic data for scientists and engineers, let's think about some important questions:

1. What is the percentage of minorities earning a bachelor's degree in engineering?
   What is the percentage of women?

2. What is the percentage of foreign nationals earning the Ph.D. degree in engineering?

3. How many blacks earned the Ph.D. in engineering in 1986?
   How many Native Americans?
   How many Hispanics?

We'll cover the answers and their implications as we go along.

Whereas the general demographic data and projections are rather complete and uncontroversial, those for science and engineering are just the opposite. This is especially true for engineers. The December 1988, issue of Engineering Manpower Bulletin states, "Available data on the number of engineers are ambiguous." The January 1989, issue addresses this problem head-on. Depending on whether one uses the Bureau of Labor Standards (BLS) or National Science Foundation (NSF) data, the United States has either 1,331,747 or 2,634,900 engineers (1986 statistics). The second figure is nearly double the first. In part, this discrepancy is due to whom each considers an engineer and the manner in which they are counted. The BLS categorizes the entire U.S. population, whereas the NSF is concerned only with scientists and engineers. Persons who are not working in an engineering occupation are not counted as engineers by BLS. Therefore, its data excludes retired engineers and trained engineers working in other occupations, e.g., armed forces, managers. NSF defines engineering broadly and includes those with degrees in engineering, including those with two year degrees if they are working as engineers; those engaged in engineering work; and those professionally identified as engineers, based on education and work experience. To confuse matters further, it is possible for a person to be regarded by the profession as an engineer, but be classified by

NSF as a scientist, e.g., an information/computer scientist. Some chemists fall into the same category.

Table 5 (Manpower Comments, March 89, p. 3) illustrates one attempt to reconcile NSF and BLS data.

One may ask, "Who cares?" Accurate data is essential for several reasons:

1. As this society becomes increasingly technological and given the problem of scientific and technological illiteracy, engineers are critical to effective technology utilization and U.S. ability to compete globally.

2. It is impossible to determine whether a shortage exists now or will exist in the future if we don't know how many there are at a given time.

3. Accurate data is needed to create and implement national policy in many technological areas.

Obviously, if the primary concern is technological literacy, it makes little difference whether we count a manager with an engineering or science background as an engineer or scientist. The technological awareness will still be there. However, if the main issue is the availability of trained up-to-date engineers and scientists for engineering and/or scientific projects, who is counted and how the counting is accomplished does make a difference. At this juncture, no count exists with any more certainty than those just cited. Therefore, we may wish to keep this in mind as the discussion progresses.

Knowing all this, is there a shortage of scientists and engineers now and/or will there be one in the future? Again, there is considerable disagreement. And, it depends, in part, upon how one defines shortage. To paraphrase Betty Vetter, editor of Manpower Comments: "When you talk about shortage, it depends on what you mean by shortage. If you are a large company who wants the best graduates from the best schools for the price you want to pay and you cannot get them, you will claim there is a shortage. However, if you are a new

Table Five

Comparison of Data Sources by Fields of Engineering

Field	NSF Total	NSF Adjusted**	BLS/CPS	BLS Matrix
Aero/Astro	117,300	56,800	93,000	51,627
Chemical	171,700	79,000	59,000	51,374
Civil	381,400	167,600	233,000	193,151
Electrical	620,700	314,600	550,000	391,529
Industrial	144,900	57,400	203,000	116,409
Mechanical	547,800	257,100	287,000	228,737
Materials/Met.	57,400	28,400	(in "Other")	17,826
Mining	18,900	10,000	(in "Other")	5,228
Nuclear	23,500	13,900	(in "Other")	13,762
Petroleum	33,400	20,600	(in "Other")	19,701
Other	517,900	212,200	324,000	242,403
Total	2,634,900	1,217,600*	1,749,000	1,331,747

* Fields do not add up to total because of rounding.

**Adjusted data derived by the author.

NSF total engineering population	2,634,900
Less those unemployed or outside the labor force	194,800
Less those employed but not in engineering	196,600
Less those whose primary work activity is management	646,100
Less those whose primary work activity is sales	64,500
Less those in the military (other than management)	10,100
Less those teaching in the educational sector	42,100
Less those with only two-year degrees	263,100
Adjusted NSF total	1,217,600
BLS total (Industry and Occupation Matrix)	1,331,747

Source: Engineering Manpower Bulletin, Dec. 1988

graduate with a 2.1 GPA from podunk college and cannot find the kind of good job you want, you will claim there is a surplus (from conversation with author)."

Betty continued with further comments. In the early 1980's, the U.S. graduated the largest engineering classes in history. That coupled with the huge number of baby boomers causes little, if any, shortages currently, although there may be spot shortages and surpluses, which historically has been the case with both scientists and engineers. However, the number of engineering and physical science students are decreasing and will probably continue to do so as the number of college age students in general and the proportion of white males that age continue to decline. Out of every 10,000 high school sophomores, only 20 will actually earn Ph.D.s in the natural sciences or engineering (Coretech, Workforce Position Paper, p. 3). There is also a drop in the percentage of college freshmen who indicate an interest in science and engineering. Betty noted that at the same time the U.S. has engineers doing work which technicians can do. She went on to indicate that we will not have enough scientists and engineers in a decade if we need as many as in the past.

On the other hand, a special supplement of Management Digest notes, "It takes four American engineers to do the same work as three Japanese. Japanese engineers out produce Americans by 33 percent." A NSF study found that U.S. engineers spend too much time on writing and drafting rather than on primary design work.

R.A. Ellis of the American Association of Engineering Societies does not think there is a current shortage. He claims that a lot of the shortage verbiage has no basis in the data and is used primarily for media headlines. However, he added that there will be a shortage in the 21st century as proportionately more blacks and Hispanics come out of high school. Historically, these groups have been less well prepared for and less interested in science and engineering. He agrees with Betty Vetter that there have always been spot shortages. For example, currently there is a small shortage of civil engineers (there is also a shortage of chemical engineers). According to Ellis, to further compound the problem, there is a very active group of engineers who claim that all the

shortage talk is a conspiracy by industry and government to increase the supply of engineers and keep salaries down.

The Science Policy Study Background Report No. 9 by the Congressional Task Force in Science Policy (December 1986) also perceives no general shortage, but then admits there have been and will continue to be spot shortages. To support this, it notes that in 1981, 28 percent of the science baccalaureate holders obtained employment outside of science and engineering while 40 percent of firms indicated a shortage of engineers. "Thus, it is individual disciplines, especially those linked with high growth or defense oriented industries, which could experience problems; not 'science and engineering' as a whole (p. 21)." They further contend there is no national market for engineers and scientists as a whole and emphasize that "college students appear to be highly responsive to market signals, and appear to shift their career choices dramatically toward fields that promise greater occupational rewards (p. 21)." To support this claim, the study cites the hugh increase in computer science and business majors in the 1980's. This has not, however, caused a surplus in these disciplines (author's comment).

To further support their thesis that shortages have been and will be only discipline specific, they discuss adjustments to supply-demand gaps. Historically, when a spot shortage has occurred, employers have rearranged jobs to utilize available skills and education and have also heavily retrained current staff. Thus, physicists, technicians, and the like become engineers due to demand or the company trains one type of engineer or scientist to switch fields. Although this is a common practice, they also argue that students flood into high demand fields so that the situation corrects itself. However, John Neale, Battelle Employment Manager, noted that there is always a lag time in this correction in such a way that the students are not ready at the same time as the demand occurs. Furthermore, it can become a quality problem when the job requires in-depth experience.

Donald Glower, the Dean of the College of Engineering at The Ohio State University looks at the shortage issue more broadly: "Although there may not be a shortage for now for the purpose of employers' hiring needs, as a society the U.S. suffers from a severe lack of technologically sophisticated people

even while our economy is becoming increasingly technological." He noted that both Japan and West Germany have twice as many engineers per capita as the U.S. Engineers in Japan fill jobs of all sorts, not just engineering positions. This creates a type of broad understanding and awareness of technology. He does not think we are building, as a society, the general technological sophistication we need to remain competitive. The example he gave to support his claim is society's general lack of understanding of nuclear energy (from conversation with author).

Fred Landis, at the University of Wisconsin in Milwaukee, has been following and analyzing engineering demography for years. He responded as follows to the author's questions about whether there will be a shortage.

> "Assuming a modest rate of growth in Gross National Product (GNP), there will be a shortage. Demographics indicate there will be a downturn in the number of white males, the traditional feeder group into science and engineering. Although some claim that the gap created by this can be filled by bringing women and minorities into science and engineering, the fact is that there has been a downturn and then leveling off of women entering engineering in particular. Except for Asians, there has also been a downturn in minorities. Even substantial intervention strategies to encourage/assist women and minorities will not sufficiently increase the numbers. This is true, even if admission and graduation standards are decreased."
>
> "Physics and math enrollments will also decline so there will be fewer of these to fill the spot shortages in engineering. To some extent, supply/demand will encourage some students to go into engineering, in particular, because of the economic rewards; but there will be fewer students no matter how you look at it, so this will only help minimally."

He noted other ways to alleviate shortages; discourage retirement and voluntary terminations. This will happen on its own, to some extent, if demand drives up salaries.

According to Fred Landis and other experts, if intervention strategies are to substantially affect the number of women and minorities going into science and engineering, these interventions will have to begin at 6th grade. Given that, it will be the year 2000 before such interventions could affect the proportions of minorities and women going into engineering. Finally, Landis noted, "Although there is a lot of discussion about this, very little effort is being made toward such interventions."

Even those who adamantly claim there are no shortages of engineers at the baccalaureate level agree that shortages exist at the doctoral level and will continue. Shortages also occur at the doctoral level for physicists and mathematicians. The Congressional Task Force previously cited notes, "Levels of graduate enrollment and Ph.D. production in science and engineering appear to be largely independent of general demographic trends (Science Policy Study Background Report No. 9, p. 21)." They further note that even though there will be fewer potential students of traditional college age starting in 1995, the demand for Ph.D.'s in academia will actually increase due to large numbers of faculty reaching retirement age. This may continue through 2010. Thus, there may be intensive competition between the academic and industrial sectors for those earning the Ph.D. In the scientific and engineering disciplines, the shortage is compounded by a high number of foreign nationals receiving doctorates (see Figures 5-8). In 1986, 55 percent of engineering Ph.D.'s were awarded to foreign nationals. (The percentage indicated by various data sources differs slightly, depending upon who is counted as a foreign national.) The percentage is also quite high for other scientific and mathematics disciplines, e.g., 44 percent of first year physics graduate students in 1987 were foreign. These large numbers of foreign nationals are a mixed blessing. There would be a severe shortage of qualified Ph.D. engineers, in particular, if some of these foreign Ph.D.'s did not stay. However, there is some indication that, for a variety of reasons, their presence in large numbers as faculty members (see Table 6), discourages U.S. students, especially women,

Percent of New Ph.D.s Awarded to Foreign Citizens, (1971 and 1986)

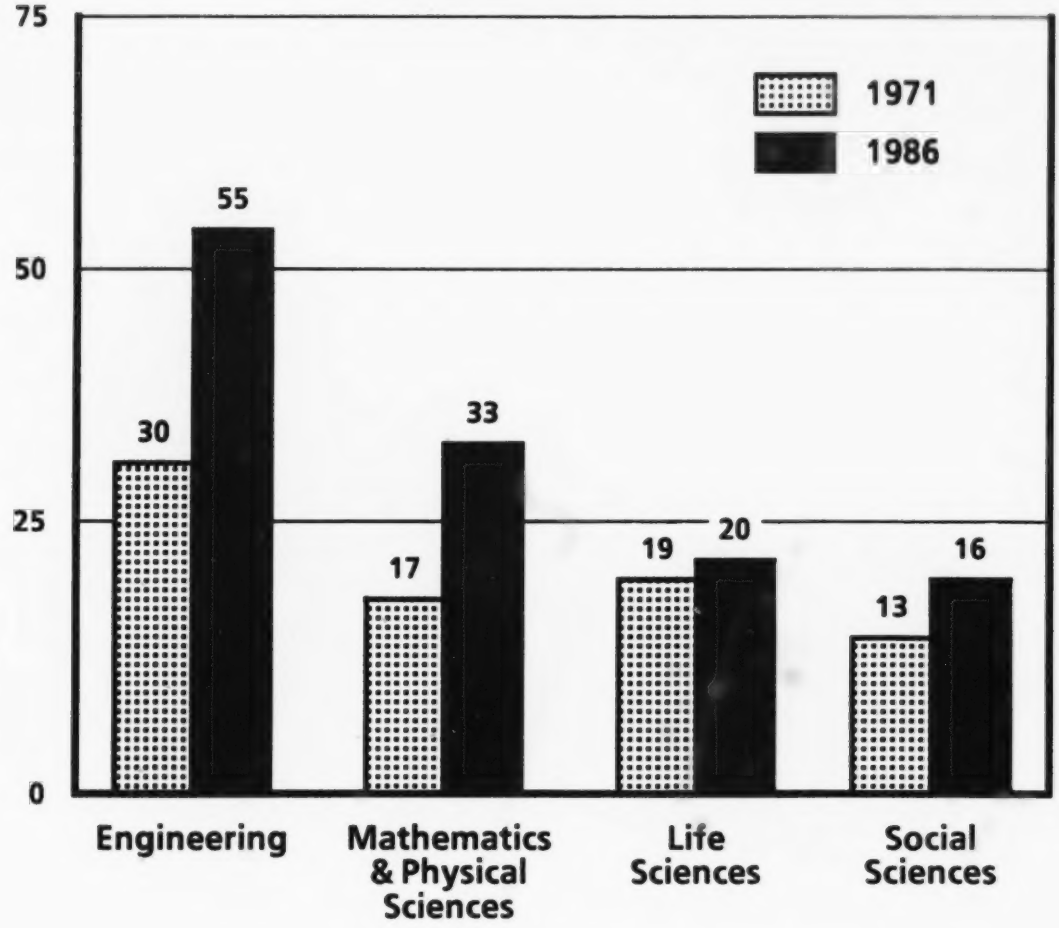


Figure Five

Source: NSF

Doctorates Awarded To U.S. Citizens in Selected Fields Per Thousand U.S. Population, Age 30

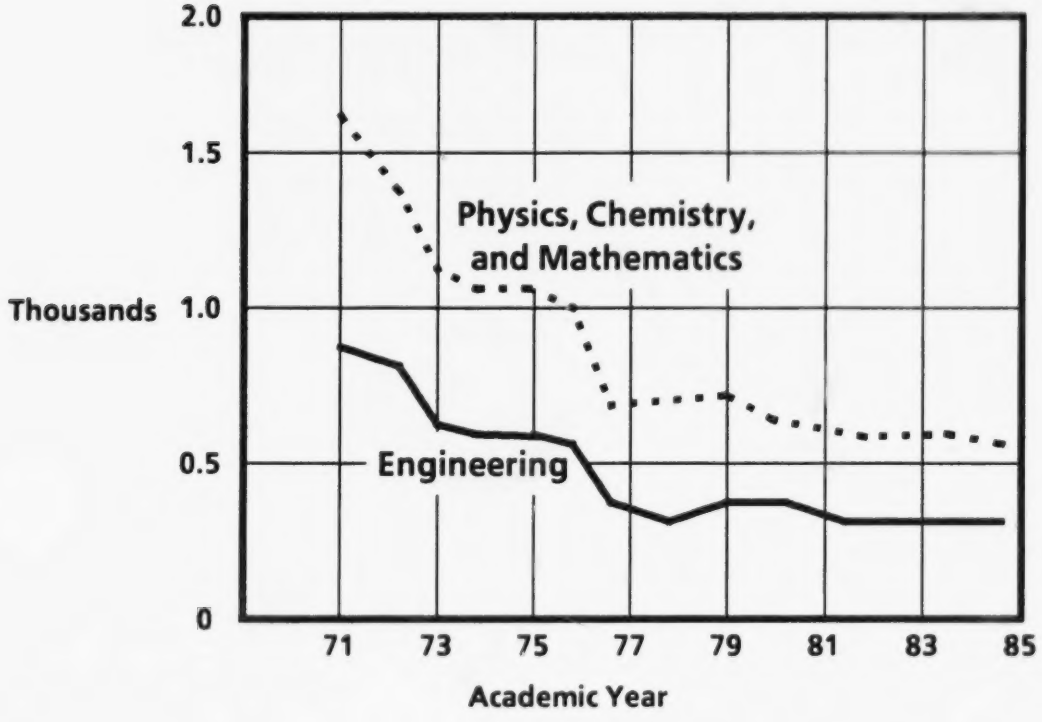


Figure Six

Source: NSF

Lightle1-13

New Ph.D. Recipients in Engineering by Citizenship, (1972-1986)

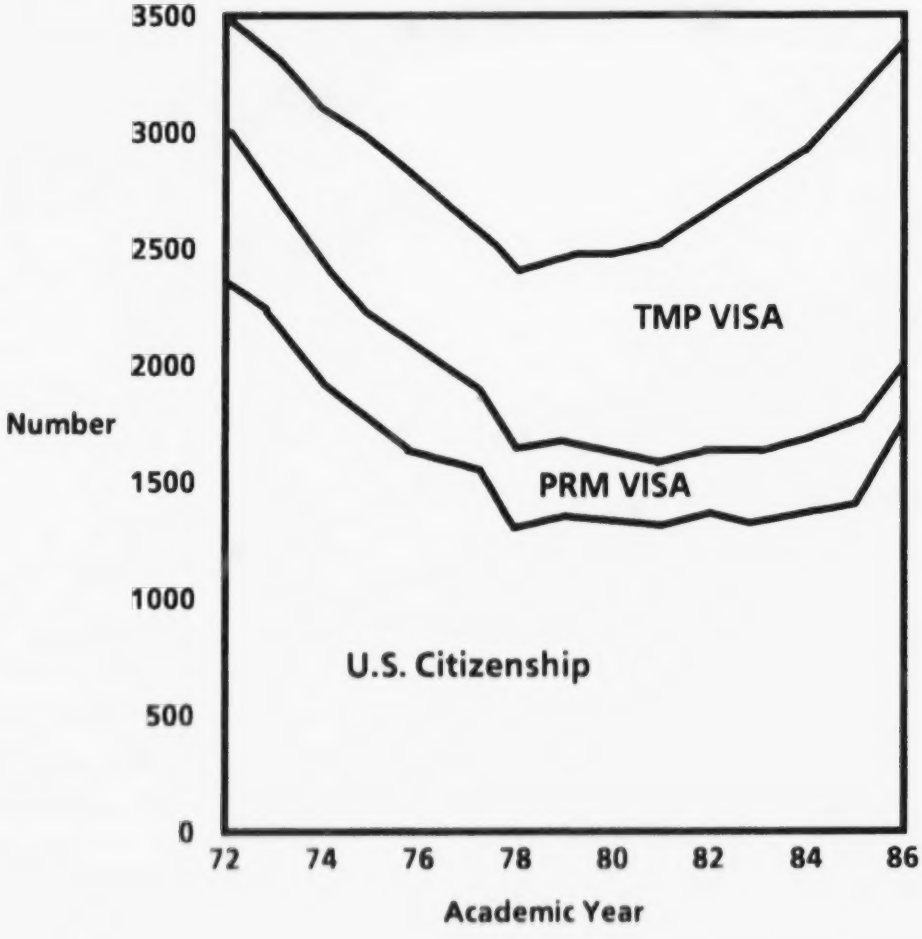


Figure Seven

Source: NSF

First-Year Graduate Physics Students By Citizenship, (1971–1987)

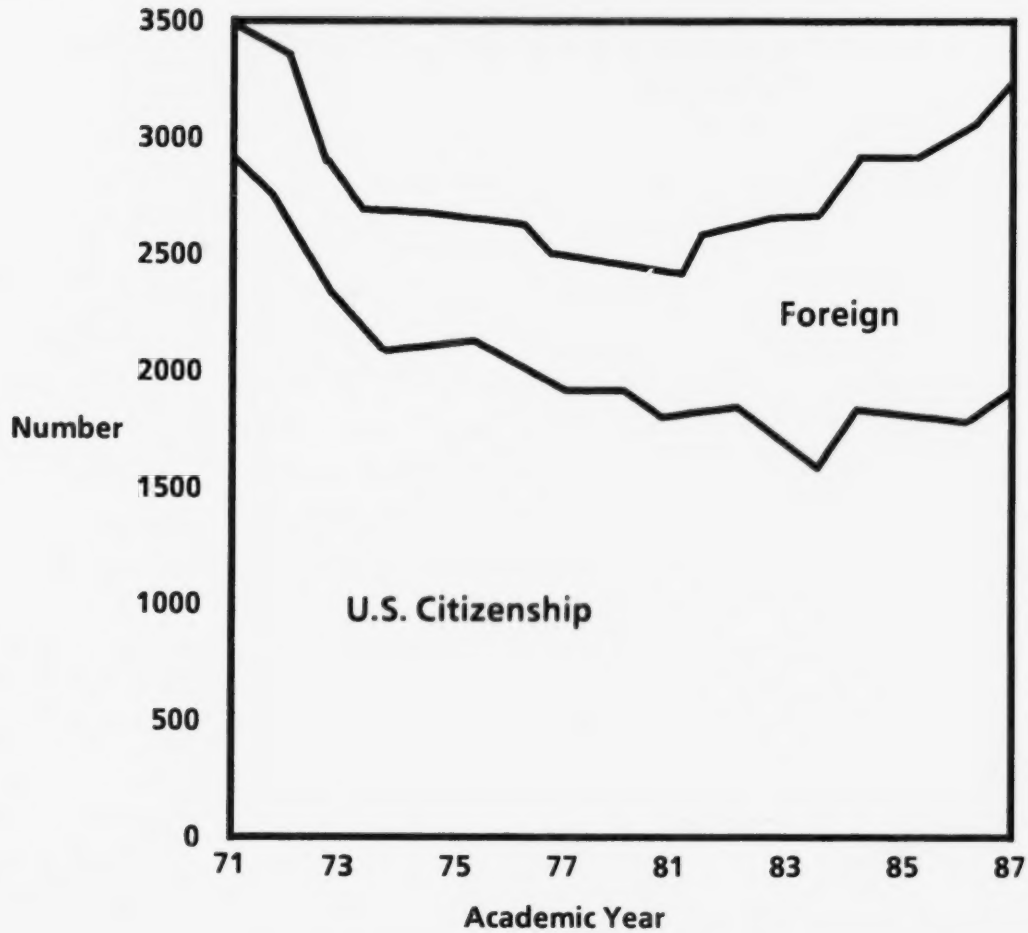


Figure Eight

Source: AIP

TABLE 6

Doctoral Faculty (Assistant Professors)

Discipline	Faculty Percent Which are Foreign
Electrical Engineering	39
Computer Science	36
Chemistry	30

(Source: Competition for Human Resources in Science and Engineering)

from entering these professions. There can be language difficulties. In addition, as far as female students are concerned, these foreign nationals frequently come from cultures where it is unacceptable for women to pursue such career choices. Data indicate that they are less likely to call on women in class and rarely appoint them as team leaders. Many educational experts also question their sensitivity to the concerns of American minorities. Fred Landis also noted that many women and minorities need role models, a role which foreign nationals are rarely able to fill.

The differences in the numbers of individuals graduating with the Ph.D. between foreign nationals and U.S. minorities obtaining doctorates is staggering. "Out of the 3,686 Ph.D.'s granted in 1986, by American universities in engineering, for example, 1,441 went to foreign students on temporary visas. In comparison, four American Indians, 38 Hispanics, and 17 blacks received a doctorate in engineering (Competition for Human Resources in Science & Engineering, p. 52)." If one includes all levels of engineering degrees that year, foreign students earned 13,451 degrees and native Americans, Hispanics, and blacks combined earned only 5,232. In 1987, at the baccalaureate level, blacks earned 3.15 percent, Hispanics 2.66 percent, and American Indians, .22 percent (see Table 7).

Other problems exist with foreign nationals. For example, firms which have substantial contacts with the Department of Defense (DOD) and the Department of Energy (DOE) may not be able to hire some newly graduated foreign doctorates

due to security clearance problems. This is also true for the government. Furthermore, there is no definitive data on exactly how many of these foreign nationals intend to stay in the U.S. permanently. Beverly Porter, Director of the Education and Employment Statistics Division of the American Institute of Physics has raised another issue: to what extent do we want to depend on foreign nationals for our supply. Some claim that those who return to their native countries will supply the competition. However, this need not be interpreted as negative. The Hudson Institute, among others, insists that the future health of the U.S. economy is dependent upon economic growth in the rest of the world and that we overemphasize and misinterpret the significance of competition. CORETECH advocates changing immigration policies to encourage the skilled to remain in the U.S. Ellis thinks the problems associated with foreign nationals is exaggerated.

One may conclude that a future shortage of scientists and engineers is likely, especially if one defines shortage in terms of optimum quality and broader societal knowledge of technology and its impacts. This shortage will become increasingly critical at the doctorate level. Various suggested solutions are both complex to implement and may not be successful, at least not for many years. However, they do merit a more in-depth analysis.

POTENTIAL SOLUTIONS

If we operate from the observation that at least some future shortages will exist in general and definitely will exist at the doctorate level for scientists and engineers, then it behooves employers to plan ahead to alleviate these shortages and curtail their effects. Some of the shortages and related problems will affect nearly all employers, others will primarily affect employers who hire scientists and engineers, especially those who hire at the doctorate level.

The shortage issues also directly relate to the following broader social issues:

- The extent to which society considers it desirable and/or essential for women and minorities to participate at higher levels in the workplace and how this can be accomplished.

- The educational crisis in terms of basic skills required in the workplace, the increasing demand for higher level technological skills, and the lower performance of U.S. students compared internationally, especially in science and math.

- The manner in which society handles the increased number of immigrants.

- The integration of family and workplace issues to meet the personal needs of workers while simultaneously meeting he needs of the corporations, government, and other segments of the workplace.

- The decreasing number of young people and increasing number of older individuals and the impacts of this change.

The following discussion will primarily address the above issues as they relate to the workforce and also review shortage solutions. However, in most cases, the interrelationship between broader social issues and workplace issues make it impossible to discuss the two totally separately.

Minorities

It is a demographic fact that the number of minorities, e.g., blacks, American Indians, Hispanics, and Asians, are increasing while the white native born population is decreasing. This will continue as long as the already mentioned birthrate differentials remain unchanged, even if there is an unlikely decrease or halt to immigration from South America and Asia. With a decreasing number of whites, as previously noted, the workplace population will be increasingly minority. Yet, with the exception of Asians, these groups are not only grossly underrepresented in the science and engineering fields, but also experience educational difficulties at the high school and general college levels.

This problem is so severe that it has gained a considerable amount of national attention. At least half the references cited in this paper consider the problem to be nearly a national crisis for black men in particular. As a part of this, by the year 2000, black women will outnumber black men in the laborforce (for whites, men outnumber women three to two). Some of this information has been briefly discussed in a previous section.

As the country's economy becomes increasingly based on technological sophistication, it needs more citizens as well as potential employees who have at least basic skills. Many employers already report difficulty locating employees with these basic skills, (see the reference, The ASPA Labor Shortage Survey). The government is so concerned about the situation that the Labor Department commissioned the American Society for Training and Development to conduct a study to determine exactly what basic skills employers want - with a specific plan to develop them. Although this skill lack crosses all segments of society, it is most severe for minorities and will impact them most. In turn, the skill shortage will more severely impact employers as the minority proportion of the labor pool continues to increase.

Authorities link the skill disadvantages of minorities to a number of social disadvantage factors including poor academic performance in school, a larger number of broken families and female headed households, and higher rates of criminal arrest records. For blacks, as Harold Hodgkinson notes, an even greater impact is caused by the cultural pressure on bright children to not

excel academically. In a key note speech at a symposium in 1987, he emphasized that we must start at age nine of we want to get and keep black children interested in science and math, and even earlier for basic skill achievement. He described the widespread cultural pressure in the black community that views academic excellence as selling out, as white behavior. If we want to get substantially more blacks into science and engineering, we are going to have to create some new interventions that address such pressures as well as teach new skills. (Competition for Human Resources in Science and Engineering in the 1990's, pp. 18-19)

Hodgkinson also addressed the growing number of black middle class as a potential ground for encouraging science and engineering study. However, he noted that cultural conflicts emerge here also and that role models are virtually non-existent. There are few black scientists and engineers anywhere and certainly few in school systems at any level. The percentage of black scientific and engineering faculty is negligible and the number of black scientists and engineers in general is only 2.6 percent as compared to their 10.4 percent general labor force participation (1982 figures).

The data on engineering participation for Hispanics appears somewhat less discouraging primarily because of the University of Puerto Rico which graduates over 500 engineers annually. Omit them from the statistics, and the situation appears less encouraging. Both blacks and Hispanics and also Native Americans demonstrate much less inclination than whites to even attend college and even less to major in quantitative type fields. They are half as likely to achieve a bachelors degree of any kind and one third to 62 percent as likely to obtain a Ph.D. Their participation in quantitative fields is even less. Furthermore, black and Hispanic high school graduates have been reducing their college going rates even though their high school completion rates have been rising. However, as already noted, basic skill problems have not been solved via public education completion.

The minority lack of participation in quantitative fields goes back to pre-college academic preparation which has been viewed by experts as the greatest factor affecting minority performance in college, especially in scientific and engineering disciplines. The attrition rates in college of minorities in

science and engineering are higher than those of whites, and highly correlate with measures of preparedness, e.g., high school grades, test scores, high school curriculum. Thus, early and intensive participation in science and math is essential. Often inner city schools, which many minority students attend, lack the necessary type of curricula and facilities. In general, black students also perceived their high school training as less adequate compared with the perceptions of whites. Studies have shown that blacks who attend predominantly white schools choose quantitative majors more frequently than those from black schools.

Another factor greatly affecting black, Hispanic, and Native American students is their parents' educational level. Students whose parents are college educated are more likely to choose a quantitative major. Financial support is another factor affecting minority participation. Parents of minorities provide one-fifth the financial support of white parents. This increases minority students' participation in financial aid programs and encourages them to seek employment after the bachelors to pay back debt rather than going to graduate school and incurring greater financial burdens. Furthermore, more minority students have to hold down full-time jobs while attending school, thus increasing the attrition rate.

Social class has been demonstrated to affect minority success in school, especially for blacks. The higher the family's social class, the greater the likelihood of choosing a science major. One study found that when blacks and whites are equated on variables such as class and academic background, blacks actually were more likely to choose science majors than whites.

Another study found that the mother's educational level greatly affected test scores for minorities. Many minority women lack higher educational levels. When one realizes that 44 percent of black and 23 percent of Hispanic households are headed by women and half to seventy-five percent are below the poverty level, the outlook becomes quite discouraging.

Discrimination also affects the participation of blacks and Hispanics in the scientific and engineering workforce. The unemployment rate for black engineers in more than twice that for whites and the rate for Hispanics is

Table Eight
Average Annual Salaries of Scientists and Engineers by Field and Sex/Race/Ethnic Group
(1982)

Field	Total	Men	Women	White	Black	Asian	Native American	Hispanic
Total, all fields	$34,000	$35,000	$26,300	$34,100	$29,900	$34,200	$34,000	$31,400
Total scientists	31,700	33,400	25,800	31,800	28,500	32,400	32,600	27,600
Physical scientists	34,700	35,500	26,400	34,900	30,100	32,500	42,500	33,600
Chemists	33,600	34,600	25,500	33,900	29,500	30,400	42,300	29,800
Physicists/astronomers	37,900	38,100	32,600	37,900	34,600	40,500	43,500	40,500
Other phys. scientists	35,000	35,700	26,300	34,900	33,400	37,100	42,100	39,800
Mathematical scientists	34,800	37,500	29,100	35,000	31,600	34,500	31,200	25,400
Mathematicians	35,400	37,700	29,500	35,600	31,800	36,200	31,200	30,000
Statisticians	32,800	36,700	28,100	33,000	30,900	28,600	(1)	17,200
Computer specialists	32,200	33,500	28,800	32,300	31,100	32,000	33,000	30,600
Environmental scientists	36,800	38,000	29,900	36,700	30,700	37,200	46,600	38,500
Earth scientists	37,600	39,000	30,300	37,500	31,200	38,100	42,200	39,800
Oceanographers	34,600	36,500	22,300	33,400	28,200	30,000	56,400	22,400
Atmospheric scientists	32,700	33,100	28,500	32,600	29,400	33,600	(1)	31,400
Life scientists	28,900	30,400	22,500	29,000	27,700	28,100	30,800	25,600
Biological scientists	28,200	29,500	22,500	28,300	28,000	27,400	25,800	24,100
Agricultural scientists	27,500	28,800	17,900	27,400	26,300	28,100	35,700	27,600
Medical scientists	38,900	42,600	28,200	39,300	271,00	32,000	34,500	30,700
Psychologists	28,800	31,700	23,900	29,000	25,900	28,400	23,300	20,400
Social scientists	30,600	33,000	24,300	30,700	26,400	34,300	29,000	24,100
Economists	34,700	35,900	29,600	34,700	31,100	37,200	28,700	31,000
Sociologists/ anthropologists	24,900	27,000	21,600	24,900	23,800	26,700	28,500	18,100
Total engineers	$35,800	$36,000	$29,000	$35,900	$31,700	$35,100	$35,000	$33,700

Source: National Science Foundation, *Science and Engineering Personnel: A National Overview*, NSF 85-302, p. 138.

higher also. Furthermore, substantial salary differences exist. National Science Foundation data (1982) found that whites on the average earn $4,000 more per year than black scientists and engineers and $2,700 more than Hispanics (see Table 8). The size of the salary differentials varied considerably by field. Minorities also are making little progress in general faculty positions. The number of minority faculty rose only 1.7 percent between 1975-1985, from 8.3 to 10 percent. Hispanics, Native Americans, and blacks remain concentrated in lower ranks. Only Asian participation rose dramatically by doubling; but their tenure rates, as with other minorities, remained well below the national average. Fred Landis noted that many minorities are more recent graduates with less work experience which tends to lower their averages somewhat.

In many reports, the data for Asians is quite different from that of other minority groups. Their participation in quantitative fields is proportionately twice that of whites in spite of the fact that their likelihood to obtain college degrees is equal to whites. However, Dr. Robert Suzuki claims that most of the Asian "success" is due to immigration and does not affect the American born who "bear the legacy of 130 years of oppression and who trace their ancestry to poor immigrant peasants (see Science Policy Study, Background Report No. 9, p. 142-3)." Nevertheless, data indicates that Asian American quantitative propensities are independent of parental educational attainment.

Given the information presented in the preceding discussion about minorities in science and engineering, it seems quite unlikely that the dramatic increase in participation necessary to make up for the declining number of white males will occur in the near future. To further substantiate this, there has been almost no change in the proportion of employed minority doctoral engineers and scientists since 1973. Even given a sizeable pool of minority students with good basic skills, which is highly unlikely, it would take massive interventions with current sixth graders to substantially increase the numbers by the end of this century. To date, this is not happening. However, a number of intervention programs are occurring throughout the country, mostly at the high school and college levels. The Ohio State University has begun a new program, Young Scholars, to begin with sixth graders. Unless there is a very large increase in such programs and at an early age, it is unlikely that black,

Hispanics and American Indian participation will show a substantive increase even by 2010.

Those colleges and universities who have improved minority participation and achievement have done so by altering their own behavior. The sensitivity of faculty, administrators, deans, and even presidents play an important role in promoting a supportive campus environment to meet the needs of minority students (Manpower Comments, March 1981, p. 18).

Women

There are women in science and engineering. 50,000 women held science and engineering Ph.D.s in 1982 (compared to 20,000 in the humanities). Women are simply less visible in science and engineering because they constitute a smaller portion of the total number. (Women in Technology, p. 33) The participation of women in science and engineering has risen dramatically in the past fifteen years. In the ten years between 1972 and 1982, the combined total for all sciences and engineering showed a 12 percent increase at the undergraduate level and a 14 percent increase at the doctoral level. The biggest increase was in engineering where the numbers quadrupled. In 1987, women were 15.9 percent of the employed doctoral scientists and engineers (Manpower Comments, March 1989). In 1973, they were only 9 percent. In 1987, the proportion of scientists and engineers in the federal government who were women was 15.4 percent. These dramatic gains seem to have eased, however. For example, in 1988, the number of women obtaining engineering degrees dropped slightly to 15.35 percent. Many experts feel the dramatic increase in female participation has not only leveled off, but will decline unless a number of affecting factors are caused to change.

For women, participation in quantitative endeavors drops off sharply between the ages of 12 and 18. Furthermore, only 1 out of 20 female quantitative graduates will go on to obtain a Ph.D., whereas, 1 out of 9 males will do so. Women also show a stronger preference for the biological sciences. One popular explanation for these differences is lack of exposure to and poorer performance in high school mathematics. Although females take fewer high school mathematics classes, the college data do not support this lack of exposure

explanation. Since 1974, 40 percent of mathematics degree recipients have been female. Currently, 35 percent of computer science degrees and 40 percent of business degrees are awarded to women. Women are not avoiding math and some sciences, but are avoiding engineering and other sciences like physics. This is in spite of the fact that once they have chosen a quantitative major, women are more likely to complete it than men (42 versus 30 percent). Nevertheless, dramatic attrition of women occurs at the graduate level. Furthermore, collegiate women also do not have equal access to the best science curricula because they are more likely to attend less prestigious small colleges rather than the most distinguished scientific and engineering universities (Ibid. p. 34).

Family is also an influential factor. According to Eccles, a psychologist at the University of Colorado, parental attitudes are a key reason why sciences remain male dominated. She finds that parents exaggerate boys' science and math abilities and underestimate girls', greatly affecting self-image, math confidence, and eventual career choice (Manpower Comments, May 1989, p. 21).

Sex role stereotyping by parents, peers, and school faculty and counselors also negatively impacts female choice. The characteristics associated with scientists, unemotionality, calmness, rationality, and independence, are not characteristics usually associated with females. "Girls who are interested in science careers must break the stereotypical mold and be willing to be associated with traditionally male attributes. Females who attend girls/womens schools and colleges show stronger preferences for math and science presumably because these stereotypes are not as meaningful there (Women in Science, pp. 39-40)." Studies have shown that girls who prefer science are seen as less attractive, less feminine, and less popular.

There has not been extensive study as to the causes of the female drop-out rate from the engineering and graduate "talent pool." However, some data throw light on likely causes. In one study, forty five percent of females in doctoral programs cited self support as a primary source of financial support, whereas only 30 percent of men did so. In addition, 22 percent of the men and only 10 percent of the women received assistantships as their primary financial support. Yet, data indicate that female students come from poorer families and

have the greatest need for financial aid. Another cost factor deals with women's colleges which are proportionately the largest source of female scientists; three of the most expensive colleges in the United States are among these women's colleges (Manpower Comments, March 1989).

The high number of foreign national engineering faculty has been cited as another cause of female lack of participation at all levels (see Table 6). This is especially significant at the graduate level where interaction between faculty and students are both more intense and more important for success. Betty Vetter also points out that the American-born faculty in engineering are filled with men who went into engineering as part of a male bastion and are frequently non-supportive of women either intentionally or unintentionally. One female graduate student told the author that this type of attitude, i.e., women do not belong here, is frequently reported regarding physics faculty in particular.

In both science and engineering almost no role models exist for women. There are few female faculty and discrimination is blatant. 17.5 percent of female faculty are neither tenured nor on a tenure track as compared to 7.2 percent for men. 73.9 percent of the men are tenured, but only 36.1 percent of women. These differences can be explained in part due to almost no women holding such academic positions until recently and therefore having less experience. However, of those with 20 years of academic employment, only 64 percent of the women were full professors as compared to 87 percent for men.

Workforce differentials are also substantial when salaries and unemployment are reviewed. In 1982, the median salary for female scientists and engineers was $26,300, only 75 percent of the median for males ($35,000). The more experience the woman has, the greater the difference (see Figure 9, Manpower Comments, March 1989, p. 18). Fred Landis told the author that because women tend to take more time away from career activities to have children and handle other family matters, there is a problem due to obsolescence. This is particularly damaging in science and engineering fields where knowledge and technological change occurs most rapidly. In March 1989, Betty Vetter cited a study which matched men and women engineers with the Ph.D. and then looked at salary differences given a thirty year career span. They found that during a

career, a woman would make $250,000 less than a man. She went on to say that many women were quitting the field; the payoff just is not there. She mentioned one female Ph.D. engineer who was quitting to go into real estate, giving up in disgust. Betty said that such behavior among women scientists and engineers is becoming more common. The strength of their feelings is of especial interest given that women are "much more likely than men to choose engineering as a career because the work itself is interesting (Will Women Engineers Make a Difference?, p. 51)," as opposed to men who enter the field because of anticipated earnings.

Unemployment rates for engineers and scientists are generally low compared to national averages. However, the rate for women is routinely two times greater than that for men, the least difference existing in computer science. Women are also twice as likely to be underemployed (NSF data).

Some experts consider these discriminatory practices to be the greatest impediment to greater participation of women in science and engineering. "The effect on women who have made the long and arduous investment in training for a scientific career can be devastating (Science Policy Study Background Report No. 9, p. 139)." The above factors are believed to significantly affect female students in the education pipeline. With no role models, negative stereotyping, the prospect of less salary for the same work, greater likelihood of un- or underemployment, and less opportunity for advancement, why spend the time and money pursuing such arduous disciplines?

Samuel Florman suggests that talented women avoid engineering for totally different reasons, i.e., they see it as lacking political power and prestige as compared with law, medicine, and business. "The perception is widespread - among minority students as well as women - that if you're smart enough to be an engineer, you're too smart to be an engineer. In other words, for the same talent and effort, other professions yield greater return (Will Women Engineers Make the Difference?, p. 52)."

Obviously, if this society hopes to offset the lack of white males, the traditional scientists and engineers, by an increase in female participation, numerous changes will have to be made. The educational system and parents will

have to emphasize science and math for girls as well as boys and at younger ages. However, this will do little if there are few rewards at the end of the pipeline. More faculty women will need to get tenure and be on tenure tracks and receive salaries comparable to those of their male counterparts so that more role models exist. Male faculty will have to exhibit greater sensitivity and provide greater support to female students, outside funding will need to increase, and sex role stereotyping will have to diminish. Without these changes, there are no increased incentives. Considering the salary issue, lack of supply of males may drive up female salaries. However, this has not occurred in the past.

The Scientific Educational Crisis

This crisis has already been mentioned in various segments. It affects everyone, not just women and minorities; and as previously mentioned, unless society addresses it head on, there not only will be a continuing shortage of scientists and engineers, but also a severe lack of citizens with basic scientific knowledge to make the rudimentary judgments necessary in a technological society. While this may affect certain minority groups most severely, it affects the ability of the entire society to meet the global challenges of the twenty first century.

Data on the failure of the U.S. educational system is everywhere. One study cited by Manpower Comments, March 1989, shows that even though verbal and mathematics skills have actually improved in the past 20 years, most students do not know how to apply them and are unable to use basic algebra or evaluate the appropriateness of scientific procedures. Forty nine percent of 17 year olds cannot compute decimals, fractions or percentages, recognize geometric figures, or solve simple equations, and 94 percent cannot solve multi-step problems or use basic algebra (p. 25). Furthermore, a survey of adults in the U.S. and Britain discovered that 90 percent are illiterate scientifically, e.g., saw astrology as somewhat scientific, thought radioactivity in milk could be destroyed by boiling, did not know whether the earth rotates around the sun or vice versa.

The curriculum and quality of instructors is solely lacking in our elementary and secondary schools. For example, in a national study, science was the only subject about which a substantial number (16 percent) of teachers felt they had not been adequately trained to teach. This is not surprising given that, on the average, elementary education students take only nine hours of science and nine hours of math (Competition for Human Resources in Science and Engineering in the 1990's, p. 35). Very few U.S. public high schools require four years of science and/or math to graduate. Less than half of high school science courses include laboratory work as part of the curriculum. A new international study of science and math skills compared students worldwide. U.S. 13 year olds fared poorly compared with others. Our best students scored no better than Japan's average students and scored behind Korea, Finland, Sweden, Hungary, Canada, and Italy. Overall, U.S. students were 15th in a field of 16.

This problem is compounded by the huge drop in federal financial support for education. For example the number of federally funded fellowships/traineeships dropped from 60,000 to less than 13,000 from 1970 to 1986. Many scientific grants closed entirely.

As previously noted, the number of U.S. citizens pursuing advanced science and engineering degrees has declined to the point that less than half of the Ph.D.'s in engineering are earned by U.S. citizens and only about two thirds of the advanced degrees in the physical sciences. This shortage is serious because advanced degrees are required for faculty and top industry researchers. It is also a problem for defense research where, as already noted, frequently non U.S. citizens cannot engage in research because of security issues.

With the coming faculty retirements (about one-third of present faculty) and the subsequent needs of academia and the other shortages discussed, we need new strategies to face these problems. CORETECH, the Council on Research and Technology, which is sponsored by a number of universities, research centers, and corporations, has created a position paper which includes recommended actions to solve the shortage and address inadequate basic scientific and mathematical education.

"Specifically, CORETECH recommends the following federal actions:

I. While recognizing that the primary responsibility for the United States' elementary and secondary education system lies with state and local government, focus appropriate attention and resources on federal mechanisms to bolster elementary and secondary science and mathematics education.

II. Substantially increase federal support for undergraduate and graduate education in the sciences and engineering and for modernization of university research facilities.

III. Expand programs to increase the percentage of women and minorities in our scientific and technical work force.

IV. Support, and stimulate, career-long, continuing education programs for our scientists, engineers, technicians, and managers of technology.

V. Foster communication and collaboration among government, industrial, and educational partners to maintain the excellence of our scientific and technical work force." (Workforce Position Paper, p. 8)

In addition to overt federal action, they advocate corporate involvement in local schools through programs in which corporate scientists work with teachers in a variety of efforts. Corporations can also provide scholarship and internship support and donate scientific equipment to schools. Additionally, the corporate segment can create a work atmosphere that encourages further training, offers internal training programs, and sponsors forums at which scientists and engineers from all sectors, academia, government, and industry, can pool resources and ideas.

Dr. James Rutherford, Chief Education Officer of the American Association for the Advancement of Science (AAAS), strongly advocates untracking, i.e., doing away with business, academic, and general tracks, and feels we need "to give everybody a good solid fundamental education in science, literature, history, mathematics, art, technology (Competition for Human Resources in Science and

Engineering in the 1990's, p. 60)." He also feels that a major problem in terms of essential curriculum change is the "absence of a clear notion of what we want to achieve in our elementary and secondary schools (Ibid, p. 63)."

David E. Koshland, Jr. in "Science," February 1989, states "Producing an adequate supply of scientists and giving scientific literacy to non-scientists both require teaching excellent science to every child at the elementary level (p. 989)." He also emphasizes math skills.

The AAAS advocates a change in scientific education to: emphasize principles and concepts rather than detailed memorization. Their report advocates a totally new teaching method in which teachers would act as project guides for projects that use all skills, not just science and mathematics. The report also includes criteria of what all 18 year olds should know to be scientifically literate. Another effort, Project 2061, is aimed at affecting schools in 15-20 years, hardly a solution for near term problems. In all these efforts, industry, government, and agencies have teamed to address this far-reaching societal problem.

Up to this point, traditional degree oriented education up through the graduate level has been addressed. One potential, partial solution to the shortage problem is to increase and emphasize lifelong continuing education and training programs for existing scientists and engineers. This would not only alleviate shortages, but also prove very useful in curtailing obsolescence, which occurs more quickly in science and engineering than in most other fields. In Focus on the Future, the National Academy of Engineering has created A National Action Plan for Career-Long Education for Engineers. In it they wrote:

> Numerous studies indicate substantial pay-offs from increased education and training:
>
> - The 1985 National Research Council report "Continuing Education of Engineers" includes a unanimous finding that education exerts a positive influence on innovation (National Research Council, 1985a).

- Motorola study: Quality engineering education produced a 30:1 payoff in revenue in the same year (Edward Bates, Motorola Internal Report, personal communication, 1987, Galagan, 1986).

- Motorola study: Statistical Quality control course produced a 29:1 payoff in reduced costs of repair and rework in the same year (Edward Bates, Motorola Internal Report, personal communication, 1987; Galagan, 1986).

- A report cited in a National Research Council study (1985b) indicates productivity improvement of 30 to 40 percent resulting from the introduction of computer-aided engineering design.

- A study cited in the journal of the American Society for Training and Development (Training and Development Journal, 1986) showed that "after adjusting for inflation, the productivity returns to on-the-job training was 12.6 percent for those with college education and 29 percent for those without college."

- A study at AT&T Bell Laboratories (Hoover, 1987) shows a fivefold increase in the productivity of the design engineering staff on circuit board designs over a period of 10 years due to application of training and CAD facilities.

It would be unreasonable to expect that such large increases as those cited above could be attained consistently over a much-expanded national effort. However, the Committee does not believe that the United States is near the limit of possible achievement for the nation's engineering community as a whole.

It is important to understand that the existing work force will be upgraded or replaced only gradually, and that changes in education and training institutions and their output affect a small percentage of the work force at any given time. As Kazis (1988) argues, reforms in

education and training are an investment, not a remedial tonic. But it is precisely this long-term view of education that must be more deeply inculcated in and institutionalized for engineers in the United States.

Management is responsible for the development and deployment of all capital resources, including intellectual capital, used in operating an enterprise. The U.S. record in managing intellectual capital can be improved, both in individual companies and organizations and on a national basis. The Committee agrees with many other groups that the United States will benefit from a continuous expansion of its intellectual capital across the broad spectrum from research scientists, to professional engineers and managers, to technicians and to a skilled work force and an informed population. The Committee also believes that engineering intellectual capital probably has the highest economic denomination of all forms of intellectual capital. (pp. 18, 19)

In spite of these pay-offs and broad company claims that they support education and training and often pay for it, the number who participate in continuing education varies considerably, from 63 percent in large urban firms to 35 percent in small non-urban firms (Ibid. p. 28), and may be insufficient to keep up with technological changes.

Often corporate philosophy and actual practice differ substantially. As Focus on the Future notes, "A well designed company infrastructure that encourages, supports, and sustains a policy of career-long education from the highest corporate level through the managers and supervisors to the line engineer is essential. It is the most likely guarantor that a program will be able to interest, enroll, and retain the number of engineers needed to make it cost-effective and successful (Ibid. p. 29)." This includes not cutting training budgets as the first to go in a crunch and clearly communicating that there is a pay-off for the employee who engages in meaningful educational activities and the pay-off is better assignments, new challenges, and broader opportunities. Focus on the Future further emphasizes employer responsibility as part of their recommended national action plan.

"All private companies and other organizations that employ engineers, including governmental agencies and not-for-profit institutions, should clarify and focus their educational objectives by linking those objectives with their overall goals. In particular, they should take the following action:

- Adopt as policy the idea that those who keep current and productive and those that consistently improve their performance are positioned to compete for the best and most challenging job assignments.

- Make it clear that the technical competence of the staff is highly valued, and be sure that a system is in place to give that philosophy credibility.

- Emphasize that the maintenance of engineering quality is a cost-effective investment by the employer.

- Maximize the effectiveness of available internal and external education programs by improving the organization's support mechanisms and policies for stimulating continuing education for its engineers.

- Design infrastructures that encourage, support, and sustain a policy of career-long education, from the highest level of the enterprise through line managers and supervisors to the industrial engineers.

- Implement education programs (both internal and external) that correspond to the objective of keeping engineers current.

- Become more aware of the characteristics of engineering professionals; learn to identify those barriers that discourage participation in education activities; create strategies to dissolve those barriers.

- Reassess the structure and activity of the in-house training offices to encourage a cooperative and productive dynamic between the human resource staff that puts programs together and the engineers for whom programs are designed.

- Communicate clearly the educational expectations they have of their employees during the recruitment process, at the point of hiring, and during orientation.

- Require their managers to maintain education practices that are in accord with the organization's overall education philosophies.

- Include as part of the performance review and reward structure for managers, evaluation of how effectively managers encourage and support the educational development of the engineers they supervise.

- Expand the increasingly widespread practice of an annual review of educational aims and objectives of technical personnel." (pp. 42,43)

Although these points focus on engineering, the same problems and solutions apply to continuing education for scientists.

Retaining Older Employees

Census Bureau and Department of Defense data indicate that more than 50,000 scientists and engineers retire annually. More than 25 percent are in their fifties and one-half are under 63. Therefore, a potential solution frequently suggested for the future scientific and engineering labor shortage is retirement delay and the rehiring of retirees. This would be a reversal of a trend that began over 100 years ago. In 1890, 71 percent of men over 65 were in the labor force. This percentage has steadily dropped to 16 percent (1986). This pattern of decline also more recently applies to men 55 to 64. Their participation has dropped from 83 percent in 1970 to 67 percent in 1986. On

the other hand, the participation rates for older women rose between 1950 and 1970 then levelled off. For example, the rate for women aged 55 to 64 increased from 27 percent in 1950 to 43 percent in 1970 and has remained near that percentage through 1986. It is probable that women's patterns may become more like those of men as larger numbers of women participate for longer periods in the labor force, qualifying them for pensions. However, this is an unknown.

Two factors greatly affect retirement decisions: income and company personnel policies. Income is affected also by the current state of the government Social Security system. At present, the system is amply funded and helped by the fact the number of workers supporting recipients is at least sufficient. However, that will dramatically change around 2010, when the first of the baby boomers begin to retire. At the turn of the 20th century, there were 8 workers to 1 retiree. This ratio could worsen to nearly one to one when the retirement boom hits around 2010. Unless retirees possess adequate private pension funds, work may become a necessity for survival. Social Security is also presently set up to limit part-time employment unless the individual is willing to incur a penalty. This limit could be changed to promote increased workforce participation.

Company personnel policies currently encourage rather than discourage retirement. Current pensions often provide an incentive to retire, but plans could be established in such a way as to encourage workers to remain. Early retirement programs obviously promote retirement rather than continued employment. Would changes affect retirement decisions? The Bureau of Labor Statistics does not think they will alter male retirement behavior. They project, "The 16 percent of men 65 and over in the labor force in 1986 will fall to 14 percent in 1990 and to 10 percent by 2000. Smaller declines show up in the 55 to 64 age group. Further declines are expected for younger men aged 45-54 (Employing Older Americans: Opportunities and Constraints, p. 13)." The same source expects older female participation to rise from 66 to 75 percent for 45 to 54 year olds and from 42 to 46 percent for the 55 to 64 age group. Since the vast majority of engineers in these age ranges are not female, the likelihood of retaining sufficient members of older male engineers to make up for the decrease in youth seems low. If employers want to reverse this

retirement trend, they "must be willing to actively recruit and maintain their older labor force. . . We could cut Social Security and Medicare (Ibid. p. 24)," a controversial idea at best.

There are negatives to early retirement beyond the issues regarding the supply of engineers and scientists. Retirees do not contribute to GNP. As to whether retirement is good for individuals, that is certainly a debatable issue. Furthermore, retirees generally experience income reduction.

This whole area is further compounded by age discrimination issues. Age discrimination cases are the fastest growing, compared to race and sex. Discrimination is fueled by many myths about aging workers. Furthermore, there appears to be a general feeling throughout the country that early retirement is a good thing. There is also a congressional trend to discourage hiring and retaining older workers by making their benefits more costly for employers. "Employers must now pay the health care costs of older employees and their spouses who would previously have been covered by Medicare. While this shift in cost was made to reduce the deficit, it has the effect of making older workers expensive and therefore undesirable, (Ibid. p. 60)."

It will require massive public education campaigns, changed pension rules, altered Social Security limitations, stronger enforcement of discrimination laws, and training programs to offset the many obstacles to continued employment for older workers. The Department of Labor's Older Worker Task Force suggests the following to encourage continued employment: eliminate the Social Security earnings test, raise income threshold to which it applies, or accelerate phase-in of the delayed retirement tax credit (Fair Employment Practices, March 16, 1989, p. 33).

The training aspect is of particular importance in terms of science and engineering. As previously noted, obsolescence takes little time to occur in many scientific and engineering fields. Continuing education is therefore crucial if retention of older scientists and engineers is to be a viable alternative in shortage situations.

Immigrants

Asian and Middle-Eastern immigrants in particular continue to contribute sizeable numbers to the scientific and engineering ranks. Given the data discussed under the sections on minorities, women, the educational crisis, and older workers, it becomes obvious that retaining a sizeable portion of these immigrants is essential to U.S. technological viability. Current estimates suggest that about one-half remain after completing their education. This could be further encouraged through more liberal immigration laws for high demand job groups. CORETECH specifically advocates adjusting immigration laws to "allow foreign nationals with needed scientific and technical training to remain in U.S. (Science and Technology Position Paper, p. 25)."

For those that stay, universities and companies may find it very beneficial to develop programs on cultural adaptation and managing cultural diversity. Generally speaking, foreign nationals come from cultures whose values and customs are very different from those in the U.S. For example, 60 percent of foreign graduate engineering students are from South and East Asia as are 32 percent of foreign undergraduate engineering students. They also comprise 54 percent of math/computer science foreign enrollment. Those from the Middle East comprise 18 percent of foreign graduate and 38 percent of foreign undergraduate engineers. (Science Policy Study, p. 60)

A few of the problems encountered when foreign nationals become professors have been mentioned. Some universities are addressing this head-on. The Ohio State University requires all foreign nationals who plan to teach, including graduate student Teaching Assistants, to take a course that includes American expectations and appropriate teaching behaviors.

Companies are also beginning to implement courses on working with and managing cultural diversity. Nationwide Insurance Companies uses a training program which includes videotapes to teach managers about the changing workforce and valuing diversity. Generally, these programs address different customs, how body language meaning varies culturally, and the differences in expectations and appropriateness. They attempt to alleviate misunderstanding, misinterpretations of behavior, and negative feelings and attitudes toward

individuals from other cultures and instill positive attitudes toward cultural differences. Such positive attitudes are essential to maintain a productive workplace or education setting.

Conclusion

The future workforce and workplace will be very different from today. There will be fewer whites and fewer traditional families. Shortages of individuals with needed basic skills will increase. Society will require increasingly greater technology sophistication. At the same time, the scientific and technological skills of the population are inadequate. Massive interventions will be required to alter the situation. Shortages of scientists and engineers may occur.

How the United States deals with the changes will determine the future. We cannot change who has been already born, but we can alter the effects. We have to change attitudes of people, of business, and of educational institutions. We can focus on the outcomes, what do we want as a society for all of us. That is the beginning.

> The problem of an adequate supply of scientists and engineers is really part of much more comprehensive problem. We are facing demographic changes in the age distributions, and significant changes in the socio-economic mix of our population. We have to learn how to deal with these changes and use them to our advantage and not let them become detrimental. The resulting damage will not show up so much in the nineties but rather in the early part of the twenty first century. Thus when we look at science education and the technical labor force we have to have a perspective of the overall system in which they are embedded. We must look at the changes in our society and in its motivations and values.
>
> We may be facing very big problems, problems that are difficult to predict accurately. They sometimes may appear almost insurmountable. But they are getting the attention and thoughts of many people. Maybe if we keep hammering away at them, we may be able to lick them. (Competition for Human Resources in Science and Engineering in the 1990's, p. 78)

REFERENCES

American Association of Engineering Societies. February 1989. "Engineering Manpower Bulletin."

Op. cit. January 1989.

Op. cit. December 1988.

Axel, Helen (editor). 1988. Employing Older Americans: Opportunities and Constraints. The Conference Board, Inc., N.Y.

Carnevale, Anthony, Gainer, Leila J., Nultzer, Ann S. 1989. Workplace Basics: The Skills Employers Want. Joint Study by American Society for Training and Development and U.S. Department of Labor.

Cetron, Marvin J., Lucken, Rebecca, McFadden, Charles F., and Weir, Barbara J. Forecasting International, Ltd. 1987. The Impact of The Changing Family on Employee Relocations: Implications for Spouse Employment. Employee Relocation Council.

Coates, Joe. June 9, 1988. Notes and material from presentation at Human Resources Planning Society symposium.

Commission on Professionals in Science and Technology. 1987. Competition for Human Resources in Science and Engineering in the 1990's. Proceedings of a symposium, Washington, D.C., October 11-12, 1987.

Commission on Professionals in Science and Technology. January-February 1989. "Manpower Comments."

Op. cit. March 1989.

Committee on Career-Long Education for Engineers. 1988. Focus on the Future: A National Action Plan for Career-Long Education for Engineers. National Academy of Engineering. Washington, D.C.

Committee on the Effective Implementation of Advanced Manufacturing Technology, Manufacturing Studies Board, Commission on Engineering and Technical Systems. 1986. Human Resource Practices for Implementing Advanced Manufacturing Technology. National Academy Press. Washington, D.C.

Council on Research and Technology. March 1989. Science and Technology Workforce Position Paper. N.Y. and Washington, D.C.

Finney, Martha I. February 1989. The ASPA Labor Shortage Survey. "Personnel Administrator," pp. 35-42.

Florman, Samuel C. November-December 1984. Will Women Engineers Make A Difference? "Technology Review," pp. 51-2. Massachusetts Institute of Technology. Cambridge, Massachusetts.

Hodgkinson, Harold L. May 1986. Guess Who's Coming to Work. Occasional Paper, No. 116. National Center for Research in Vocational Education. Columbus, Ohio.

Johnston, William B. and Packer, Arnold E. 1987. Workforce 2000, Work and Workers for the 21st Century. The Hudson Institute. Indianapolis, Indiana.

Hornig, Lillis. November-December 1984. Women in Science and Engineering: Why So few? "Technology Review." pp. 30-36, 38-41. Massachusetts Institute of Technology. Cambridge, Massachusetts.

Hughes, H. Patricia. November-December 1984. Women Working: A Field Report. Technology Review," pp. 37, 38, 47. Massachusetts Institute of Technology. Cambridge, Massachusetts.

Kahle, Jane Butler (editor). 1985. Women in Science. The Folmer Press. Philadelphia, PA.

Keller, Evelyn Fox. November-December 1984. Women and Basic Research: Respecting The Unexpected." Technology Review, pp. 44-47. Massachusetts Institute of Technology. Cambridge, Massachusetts.

"Management Digest." Special Supplement. The Engineering Gap.

McLaughlin, Steven D., Melber, Barbara D., Billy, John O. G., Zimmerle, Denise M., Winges, Linda D., and Johnson, Terry R., 1988. The Changing Lives of American Women. The University of North Carolina Press, Chapel Hill.

Moen, Phyllis. 1988. Women as a Human Resource. Draft paper.

National Institute of Business Management. February 15, 1989. "Personal Report For The Executive."

National Science Foundation. April 1987. The Science and Engineering Pipeline. PRA Report 87-2.

Office of Educational Research and Improvement, 1987 and 1988. Digest of Educational Statistics. U.S. Department of Education, National Center for Education Statistics.

Office of Technology Assessment, Task Force on Science Policy, Committee on Science and Technology, U.S. House of Representatives. December, 1986. Demographic Trends and the Scientific and Engineering Workforce. Science Policy Study Background Report No. 9. Washington, D.C.

Riche, Martha Farnsworth. February 1988. America's New Workers. "American Demographics," pp. 34-41.

Traweek, Sharon. November-December 1984. High Energy Physics: A Male Preserve. "Technology Review," pp. 42-3. Massachusetts Institute of Technology. Cambridge, Massachusetts.

Tuckle, Sherry. November-December 1984. Women and Computer Programming: A Different Approach. "Technology Review," pp. 48-50. Massachusetts Institute of Technology. Cambridge, Massachusetts.

U.S. Department of Commerce, Educational Attainment in the United States: March 1986 and 1987. Population Characteristics, Series P-20, No. 428. Bureau of the Census.

U.S. Department of Commerce, Projections of the Population of the United States, by Age, Sex, and Race: 1983 to 2080. Current Population Reports, Population Estimates and Projections, Series P-25, No. 952. Buearu of the Census.

Wetrogan, Signe I, Projections of the Population of States, by Age, Sex, and Race: 1988 to 2010. Current Population Reports, Population Estimates and Projections, Series P-25, No. 1017. U.S. Department of Commerce, Bureau of the Census.

White Men Outnumbered. August 1988. "American Demographycs," p. 18.